OPINION

by **Prof. Tania Pencheva, PhD**
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Regarding a procedure of promotion to the **educational and scientific degree "Doctor of Philosophy"**
Area of Higher Education: **5. Technical Sciences**
Professional Field: **5.3. Communication and Computer Technology**
Scientific specialty: **Computer Systems and Technologies**

Author of the dissertation thesis: **Stela Dimitrova Todorova**
Title: **Research of the Indexed Matrices and Their Applications**

According to Order No. 236/03.07.2024 of the Rector of the University "Prof. D-r Assen Zlatarov" – Burgas, I was appointed member of the Scientific Jury for defence of the dissertation thesis by the PhD student **Stela Dimitrova Todorova** for the acquisition of the educational and scientific degree "Doctor of Philosophy".

As a member of the Scientific Jury, I have been provided with:
1. A dissertation thesis for acquisition of the educational and scientific degree "Doctor of Philosophy"
2. A synopsis of the dissertation thesis
3. Copies of the publications which the thesis is based on
4. Other procedure-related documents

The dissertation thesis of **Stela Todorova** is 113 pages long and comprises an Introduction, five chapters, conclusions, formulated contributions, a list of 5 publications on the thesis, a declaration for originality of the results, and a bibliography of 213 literature sources. The thesis has been illustrated by 32 figures and 1 table. In the provided form, the dissertation thesis corresponds to the specific requirements defined in Art. 27(2) from the Council of Ministers' Regulations on the Implementation of the Academic Staff Development Act in the Republic of Bulgaria (ASDARB).

The PhD student **Stela Todorova** has presented **"the aims and objectives"** of her dissertation thesis in the following way:

1) The aim of the dissertation thesis is to find a solution of matrix equations composed of indexed matrices which elements are real numbers and intuitionistic fuzzy pairs.
2) Another task is to be investigated the properties of the determinant and permanence of indexed matrices.
3) Representation of module construction sets and logic modules with indexed matrices.
4) Representation of the installation locations of the elements of combinational logic circuits with indexed matrices.
5) Investigating of random processes with indexed matrices.
6) Application of indexed matrices with the program Excel.
7) Representation of logic values set by Arduino controller pins configured as outputs with an indexed matrix.

The timeliness of the dissertation thesis is justified by the fact that in recent decades there has been an ever-increasing interest in index matrices, both in theoretical and applied aspect.

The presented list of publications on the topic of the dissertation thesis by **Stela Todorova** includes **5 publications** – 2 as the only author and 3 in co-authorship. The PhD student is the first author in all of these publications, which unequivocally demonstrates her contribution to the achieved and presented research results. **Two of the publications are in SJR journals, one each in quartiles Q3 and Q4.**

The presented synopsis of the dissertation thesis is 46 pages long in its Bulgarian version and 45 pages long in English. It covers **to a great extent** the essence and contents of the dissertation thesis, including the aim and the objectives, as well as their execution and the results achieved. However, **I cannot but note the confused numbering of the sections in Chapter 2** (only in the synopsis in Bulgarian), the absence of "Chapter 4" in the title when presenting its results, as well as **the complete absence of Chapter 5.** In the synopsises both in Bulgarian and in English, **there are neither cited sources in the text nor bibliography.**

Based on the research elaborated in the dissertation thesis, **Stela Todorova** has formulated **8 contributions**, among which **1 scientific, 5 scientific-applied** and **2 applied**, of which **I accept only the scientific contribution, and only in the part for solving matrix equations with index matrices.** The rationale for this is contained in the following main criticisms I have for the dissertation thesis:

1) The content of the dissertation thesis does not include the Introduction, Conclusion, Contributions to the dissertation thesis, List of publications on the dissertation thesis, Declaration of originality and Bibliography.

2) Chapter 1 "Introduction to the Theory of Indexed Matrices" appears as a literature review of both the theoretical developments in the theory of index matrices and their applications. It is most logical to define the aim and objectives of the dissertation thesis as a result of this overview, whereas they are given in advance in the Introduction of the dissertation thesis.

3) The aim of the dissertation thesis and the objectives with which this aim is to be fulfilled must be differentiated and specified.

4) In subsection 2.1.2 of the thesis, on p. 24 and 25, there are serious errors of a mathematical nature in the formulas representing the solutions of equations 4-6 (p. 24). The results presented in this subsection are published in Publication 2. The errors can be considered as technical, but unfortunately they have not been identified by the PhD student and have not been corrected at least in the dissertation thesis.

5) I note the unnecessary repetition of the definition of an index matrix (IM) in subsection 2.2 on p. 28 and at the beginning of Chapter 5 on p. 70, after Chapter 1 "Introduction to the theory of indexed matrices" has already introduced it.

6) There are also a number of mathematical statements in the dissertation thesis that need a comment from the PhD student:
   - The condition "For example, here and below, if R is the set of real numbers and $\circ \in \{+, -\}$, then e0 is "0 and when $\circ \in \{\times, :\}$, then e0 is "1"" (p. 6) is formulated vaguely.
   - Is the condition "Let us have the indexed matrix A which elements are real numbers, and $k_0 \notin K$ and $l_0 \notin L$ be two indices" (p. 6) correct?
   - Is the statement $V(\neg p) = \langle \mu(p), v(p) \rangle$ correct, given that $V(p) = \langle \mu(p), v(p) \rangle$ (p. 11)?

- Is the statement $\langle b_{Ck,Cl}, c_{Ck,Cl} \rangle = \langle 1, 0 \rangle$ (p. 17) correct?
- The condition "When we must solve equation (1), we see that if $K - P \neq 0$, i.e. when there is $k \in K - P$, then $k \in (K \cup Y) - P$ that is impossible." (p. 20) is formulated vaguely (similarly to solving equation 3 on p. 23 and equation 5 on p. 27).
- In subsection 2.2. (p. 27) it is not clear whether the presented definitions of the determinant and the permanent include a contribution of the PhD student?
- A comment for the proof of Lemma 2 in subsection 2.2.1 (pp. 28-29) is missing, while Lemma 2 is used for the proof of Lemma 4.
- The index matrix in subsection 2.2.2 (p. 33) does not correspond to its description above. Furthermore, the application of IM to the undefined notion of a block diagram is not entirely clear from the exposition.
- Are the conditions $1 \neq j \neq n$ and $1 \neq i \neq m$ (p. 41) correct when presenting a functional-constructive module with IM?
- Is the distance formula on p. 47 correct?
- What is the point of introducing the index matrices B, C, D, E, F and G (p. 60) when their elements match the elements of matrix A?
- and many other remarks of a similar nature.

7) Much of the information presented in Chapters 3, 4 and 5 would have been more appropriately placed in the literature review, i.e. in Chapter 1, which is designated as introductory and overview.

8) The results presented in Chapters 3, 4 and 5 have not actually been published, as also mentioned in the analysis of the publications of the dissertation thesis below. In my opinion, the results in these chapters have no scientific impact (especially those in Chapter 5 "Representing an Index matrix with a table in Excel"), and I consider the inclusion of such general "reflections on the application of IM" unacceptable for a dissertation thesis. Moreover, Chapter 3 is nearly 20 pages long, and Chapter 5 is over 20 pages long, with huge figures.

9) There are extremely many errors regarding mathematical expressions, including different number of opening and closing brackets, quotation marks, etc.

10) There are also extremely many syntactic and lexical errors, including „пермунента" (in the "Aims and objectives of the dissertation thesis", both in the dissertation thesis itself and in the synopsis in Bulgarian), „намири", „целичислена", etc. I should also note the incorrect use in English of the term "indexed", instead of "index" matrices, as introduced by Academician Krassimir Atanassov.

I also have serious critical remarks regarding the publications related to the dissertation thesis:
1) What is presented as **Publication 2** is a prepared text, but not a publication with the attributes of edition, issue, pages, year. When referring to the Internet (https://link.springer.com/chapter/10.1007/978-3-031-45069-3_4#citeas), it appears that the article has indeed been published and should be cited as follows:
Todorova, S. (2023). *On the Solutions of Some Equations with Intuitionistic Fuzzy Index Matrices. In: Atanassov, K.T., et al. Uncertainty and Imprecision in Decision Making and Decision Support - New Advances, Challenges, and Perspectives. IWIFSGN BOS/SOR 2022 2022. Lecture Notes in Networks and Systems, vol 793. Springer, Cham, 32-38.* https://doi.org/10.1007/978-3-031-45069-3_4

2) **There are serious mathematical errors in Publication 2 itself**, as well as in subsection 2.1.2 of the dissertation thesis, which presents the results for solving matrix equations with index matrices whose elements are intuitionistic fuzzy pairs. I do not question the fact that the article went through a peer review process, but **although the errors may be regarded as technical, they are still undeniable.**

3) **Publication 4 does not reflect the results** presented in the dissertation thesis regarding the design of electronic circuits with Arduino, since **there is no application of IM** in the publication. Actually, **Publication 4 is not relevant to the dissertation thesis.**

4) **Publication 5** refers to the recycling of rechargeable lithium-ion batteries, which is not mentioned in the dissertation thesis. Thus, **Publication 5 is not relevant to the dissertation thesis either.**

5) The aforementioned also outlines **2 other indisputable facts**: 1) The results of Chapters 3, 4 and 5 **have not been published**; and 2) **3 articles** remain on the dissertation thesis, one of which (**Publication 2**) is the publication with **the mentioned errors of a mathematical nature**, and another one (**Publication 3**) is a review. **Only the results of Chapter 2 have actually been published.**

I have not had the opportunity to know **Stela Todorova** personally, but the acquaintance mediated by her dissertation thesis and publications provokes me to recommend her to be **much more critical and demanding of herself in the future.** At the same time, I have the honour of **personally knowing both of her supervisors as young, but established and successful scientists, and I appeal to them to be critical and responsible in the training of PhD students.**

In forming the overall assessment of the dissertation thesis, one should render account of the requirements formulated in the ASDARB and the Regulations of the University "Prof. D-r Assen Zlatarov" – Burgas on its implementation, according to which the PhD student **Stela Todorova formally meets** the requirements for acquiring the educational and scientific degree "Doctor of Philosophy".

With respect to all of the above, I certify that the requirements for awarding the educational and scientific degree "Doctor of Philosophy" set in the ASDARB and in the Regulations of the University "Prof. D-r Assen Zlatarov" – Burgas on its Implementation have been formally fulfilled. Despite the recognized scientific contribution to solving matrix equations with index matrices, the critical notes regarding the dissertation thesis and the publications prevail over the results obtained in Chapter 2. Based on the aforementioned, I cannot give a positive evaluation of the dissertation thesis and I would not recommend the respected members of the Scientific Jury to vote for awarding Stela Dimitrova Todorova the educational and scientific degree "Doctor of Philosophy" in professional field 5.3. Communication and Computer Technology, scientific specialty Computer Systems and Technologies.

10 September 2024
Sofia

Signature: ..... Подпис заличен Чл.2 от ЗЗЛД

(Prof. Tania Pencheva, PhD)