Review

of the thesis of Alexander Marazov
"Deep Neural Networks for Medical Diagnostics",
presented for awarding the educational and scientific degree "doctor"
in Professional area 4.6 Informatics and Computer Science

by Prof. Dr. Maria Nisheva-Pavlova, Faculty of Mathematics and Informatics –
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Pursuant to Order 911/28.05.2024 of the Director of the Institute of Biophysics and Biomedical Engineering – BAS I was appointed a member of the scientific jury for the defense of the submitted thesis in professional area 4.6 Informatics and Computer Science, entitled "Deep Neural Networks for Medical Diagnostics". At the first meeting of the scientific jury, I was designated as a reviewer for this procedure.

1. General characteristics of the dissertation and the presented materials

The dissertation contains 162 pages of text, including an introduction, five chapters and conclusion, as well as several sections with a list of abbreviations, summary of the contributions, directions for future work, list of publications, declaration of originality of the results, list of references, four appendices.

In addition to the dissertation, the following documents are also presented:

- abstract in Bulgarian and abstract in English;
- list of publications on dissertation results;
- copies of publications on dissertation results;
- list of noticed citations of the publications on dissertation results;
- European-style CV;
- copy of diploma for completed higher education;
- copies of certificates for passed exams within the framework of doctoral studies.

2. Applicant data

Alexander Marazov has a Master's degree in Applied Mathematics (Computational Mathematics and Mathematical Modeling), acquired in 2013 at the Faculty of Mathematics and Informatics of Sofia University St. Kliment Ohridski. During the period 2013 – 2023, he worked in various places as a specialist in data analysis and machine learning. In 2019, he was enrolled in part-time doctoral studies at the Institute of Biophysics and Biomedical Engineering at the Bulgarian Academy of Sciences.

I have no immediate personal impressions of the applicant's work.

3. Relevance of the research area and significance of the research problem

The dissertation is devoted to research in the field of deep machine learning models. It proposes solutions with convolutional neural networks to tasks related to the diagnosis of Alzheimer's disease stages, using the apparatus of intuitionistic fuzzy sets and intercriteria analysis.

The field of research in the dissertation is complex and topical, its relevance being determined by the rich modeling capabilities that convolutional neural networks provide, their potential applications in many modern areas of data science, as well as the great public importance of the diagnostic problem being solved.

The goal of the dissertation and the tasks for achieving this goal, which the doctoral student defines, have been determined after a study of the model capabilities of the used theoretical apparatus in solving problems in the selected field of application. The goal set is realistic and the tasks are formulated in accordance with the goal.

4. Analysis of the content, results and contributions of the doctoral thesis

The dissertation consists of an introduction, five chapters, a conclusion, a reference list and four appendices.

The introduction presents the research area and the structure of the dissertation and summarizes the content of its particular chapters and the results achieved. The goal and specific research tasks of the dissertation are clearly formulated.

The first chapter has an overview character. It briefly presents the theory and applied aspects of the apparatus of neural networks and convolutional neural networks in particular and

intuitionistic fuzzy sets. The basics of the intercriteria analysis method are reviewed. The characteristics and stages of Alzheimer's disease are discussed.

The second chapter is devoted to the presentation of results of the doctoral student in connection with the application of convolutional neural networks for the diagnosis of Alzheimer's disease. The particular components of the proposed solution and the obtained experimental results have been analyzed.

In the third chapter, an approach proposed by the applicant is discussed, which allows a significant improvement of the results presented in the previous chapter by aggregating the predictions of several suitably ordered classifiers.

The fourth chapter presents original results related to the application of the intercriteria analysis to assess the credibility of the approach to solving classification tasks presented in the third chapter.

The fifth chapter is devoted to a study of the complexity in computing the inter-criterion counters. An approach has been proposed and implemented to reduce the necessary computations and, accordingly, improve the speed of the algorithm for intercriteria analysis.

The conclusion contains a summary of the results obtained. As separate subsections are included: possible directions for future work in the field of research; formulation of the contributions of the dissertation; list of publications; declaration of originality of the results.

The list of references includes 146 titles. The manner of citing them in the text of the dissertation testifies to a very good knowledge of the state of research and applied developments in the chosen field.

Four appendices have been added to the dissertation, which contain source code created by the doctoral student, implementing respectively: an algorithm for computing the inter-criterion counters; computing of inter-criterion scores of an ensemble of classifiers; finding a weighted average; computations related to the proposed method for improving the speed of the intercriteria analysis algorithm.

The main scientific and applied scientific contributions of the doctoral thesis of Alexander Marazov may be formulated as follows:

- New methods for inferring solutions to classification tasks based on intercriteria analysis and the Kemeny-Young method in machine learning are proposed.

- An original method for evaluating inferred solutions to classification problems in terms of intuitionistic fuzzy sets is proposed, which is based on intercriteria analysis.
- A method for applying threshold values to degrees of membership and uncertainty has been developed, which increases the accuracy of the selected results.
- An algorithm is proposed to improve the speed of intercriteria analysis.

The following can be mentioned as most significant applied contributions of the doctoral thesis:

- A convolutional neural network was implemented for the diagnosis of Alzheimer's disease stages. The model training procedure can be adapted for imaging diagnostics of other diseases.
- Software implementations of the developed new methods for inference and evaluation of solutions to classification tasks are proposed.
- A program code which implements thresholding of membership and uncertainty degrees was developed and applied to the Alzheimer's disease classification task.
- A program code has been developed to improve the speed of intercriteria analysis to $O(n \log(n))$.

The doctoral thesis makes very good impression with the scope and depth of its presentation. The field of research is modern and complex, and achieving significant results in it requires serious interdisciplinary knowledge and skills. The achieved results are original and significant and fully correspond to the set goal.

5. Publications on the doctoral thesis. Reflection on the works of other authors

The results obtained in the dissertation are presented in four papers, published as follows:

- one paper – in the journal *Mathematics* (IF 2.3 for the year of publication, JCR – Q1/Mathematics);
- one paper – to appear in 2024 in the *International Journal Bioautomation* (SJR 0.14 for 2023);
- two papers – in the journal *Annual of "Informatics" Section of the Union of Scientists in Bulgaria.*

Two of the publications in this list are single-authored and two are co-authored. For co-authored publications, the personal contribution of the individual co-authors is not explicitly stated. I suppose that all co-authors have contributed equally to each of the collective publications.

Data is presented on one noticed citation of one of Alexander Marazov's publications based on the results of his dissertation in a paper of another author.

In this way, the requirements of the Regulations for the terms and conditions for acquiring scientific degrees and for holding academic positions at the Bulgarian Academy of Sciences and at the Institute of Biophysics and Biomedical Engineering have been fulfilled and even exceeded. However, the fact that there is no data on the participation of the applicant with presentatons at appropriate scientific conferences during the period of his doctoral studies does not make a good impression.

6. Abstract

The abstract (submitted in Bulgarian and in English) meets all the requirements for its preparation and fully and accurately presents the topic, purpose, content, achieved results and contributions of the dissertation.

7. Critical Remarks and Recommendations

My more substantial criticisms of the thesis can be summarized as follows:

- In places in the text, the wording is incomplete and/or inaccurate. This is particularly unacceptable in terms of the wording of the dissertation's goal and the results obtained.
- The literature review is not focused on the goal and tasks of the dissertation. In particular, it does not analyze the most significant achievements and open questions in the application of deep neural networks for the purposes of medical diagnostics. In the contributing chapters of the dissertation, there is no clear comparison of solutions proposed by the applicant with the result(s) of other authors.
- In places in the text, there are inappropriate terms in Bulgarian.
- Grammatical and typographical errors were made that could have been avoided with more careful work on the text of the dissertation.

I recommend the applicant to continue his research on the topic of the dissertation and to implement at least some of the indicated ideas for future work.

8. Summary

Summing up, I consider that the doctoral thesis of Alexander Marazov satisfies the requirements of the national regulations and the specific conditions and requirements of the Bulgarian Academy of Sciences and the Institute of Biophysics and Biomedical Engineering. Its author has achieved significant research results that make an original contribution to the chosen field of study. My assessment of the dissertation, the abstract, the publications and the scientific contributions of their author, Alexander Marazov, is **positive**.

Therefore, **I advise the honorable scientific jury to award to Alexander Marazov the educational and scientific degree "doctor" in professional area 4.6 Informatics and Computer Science**.

Sofia, August 2, 2024

Prof. Dr. Maria Nisheva-Pavlova