Dr hab. inż. Aleksandra Kawala-Sterniuk
Profesor Uczelni
Wydział Elektrotechniki, Automatyki i Informatyki
Politechnika Opolska
ul. Prószkowska 76
45-758 Opole
a.kawala-sterniuk@po.edu.pl

**OPOLE UNIVERSITY
OF TECHNOLOGY**

Opole, 25.10.2023 r.

Review Report on Doctoral Thesis

PhD candidate: **Mgr inż. Estera Kot**
Thesis title: **"„Multimodal Medical Image Processing Methods for Computer-Aided Diagnosis Support System of Brain Tumors"**
Supervisor: **dr hab. inż. Krzysztof Siwek, prof. uczelni**
Co-Supervisor: **dr inż. Zuzanna Krawczyk**
Institution: **Politechnika Warszawska**
Doctoral Study Programme/Scientific Discipline: **Technical Information Technology and Telecommunications** (Informatyka Techniczna i Telekomunikacja)

This review has been carried our in response to the Scientific Council for Computer Science Discipline invitation from 27th June 2023.

The purpose of this review is to determine whether this doctoral dissertation, authored by **mgr inż. Estera Kot**, meets the requirements for theses at this stage of education (defined in art. 13., ust. 1. Ustawy o stopniach i tytułach naukowych) and whether it meets the conditions listed in the following points:

1. Relevance of the chosen dissertation topic.

Ad. 1. Growing interest in various medical imaging techniques has led to their rapid development necessity. Medical professionals together with computer scientist analyse more and more biomedical data (images) from various modalities. Implementation of modern artificial intelligence-based algorithms allow to obtain useful information for inter alia diagnostic purposes. Analysis of biomedical data is a very challenging task as it is very time-consuming, data is prone to various external artifacts occurrence, which may result with errors.

This thesis presents methods for multimodal medical images' processing based on a multi-stage process with the use of neural network models with various architectures, which may enable efficient and effective brain tumours' detection and segmentation. The proposed in this dissertation methods are computer-aided support for among the others radiologists.

The chosen topic is very **up-to-date** and **relevant** to the scientific discipline: **Technical Information Technology and Telecommunications,** as it applies computer science-based methods to support medical professionals.

2. Fulfilment of the dissertation objectives and contribution to the scientific field.

Ad. 2.
The PhD candidate defined the following <u>research thesis</u>:

- *"The methods based on a proposed multi-stage deep learning pipeline that combine multiple neural networks of various architectures are capable of performing meaningful detection and segmentation of brain tumors and are able to be utilized in order to support radiologists during both the diagnostic stage and treatment planning process"*

The Net model accuracy was **97.39%** and **7.76%** loss, and the error value was only 0.46%. These results allowed proved the effectiveness of the proposed method and in my opinion they **meet the requirements for doctoral theses**.

The implementation of machine learning-based methods for the purpose of biomedical data analysis, in particular brain signals, is currently a very "trendy" topic. In my view, given the research outcomes and the chosen research methodologies and tools, this work carries substantial influence on the advancement of the scientific field: **Technical Information Technology and Telecommunications.**

3. Dissertation content.

Ad. 3. For this doctoral thesis purposes, the author designed and developed her own MeDAPR (Medical Data Processing) system, which significantly improves the diagnostic process of brain glioblastoma based on analysis of CT, PET and MRI images. Similar solutions using additionally MRI data, and not only CT and PET images, have not been found in scientific publications, which is a world-class innovation. The proposed solution allows any type of examination: CT, CT-PET, MRI, CT-PET-MRI.

The designed system integrates both traditional methods such as Edge and Chan-Vese algorithms, as well as state-of-the-art deep neural networks such as YOLO v.4, Mask RCNN and U-Net. Additionally, the system includes a U-Net architecture generator that uses a proprietary equation to determine the network depth depending on available input data, such as e.g. medical images.

4. Evaluation of the formal aspects of the thesis.

Ad. 4. The dissertation consists of **161** pages, including title page, table of contents, **135** references. It contains **11** chapters (including Abstract, List of Figures, List of Tables, List of Abbreviations, Publications and Bibliography), **66** figures, **20** tables and **21** equations.

As mentioned above - the dissertation is divided into **11** chapters, including Publications and Bibliography (unnumbered). The **first** chapter contains an introduction to the topic of the dissertation, a discussion of the research problem and the research thesis. The **second** chapter presents an outline of the principles of operation and diagnostic applications of medical imaging devices such as CT, PET and MRI). It also describes currently used methods of radiotherapy for brain tumours. The **third** chapter contains a

literature review on the use of deep networks to analyse biomedical images, especially in applications involving the segmentation of anatomical structures and image fusion (registration) of various modalities. It also describes the limitations of currently used methods. The **fourth** chapter presents the proprietary MeDAPR (Medical Data Processing) system. The properties of several of the most important deep network architectures used by the author of the thesis are also discussed. Chapter five describes the image segmentation algorithms developed as part of the doctoral thesis using the active contour method, and in particular its non-parametric version called the level set method. In chapter **six**, the author described her experiments related to the segmentation of images containing tumours using deep networks with various architectures. Chapter **seven** presents a proposal for an IT platform using the cloud computing to train and run artificial intelligence models in batch mode, which enables federated learning. Chapter **eight** is a summary of the doctoral thesis, which contains the most important results obtained and outlines directions for further research. Chapter **nine** contains acknowledgments. Chapter **ten** (unnumbered) list of the doctoral student's publications. The last (also unnumbered) **eleventh** chapter contains a list of literature cited in this work.

The work is written entirely in an excellent English.

In the further part of this dissertation review, I will point out both the positive and negative features of this doctoral thesis.

5. Positive qualities of the thesis.

Ad. 5. The design of experiments is very well organised and the research thesis is very well defined. The work is short, concisely written, but efficiently presents research problems and their solutions. Based on the obtained results - the described problem and the aim of this work have been solved. Quality of all figures and tables quality is proper (legible). The dissertation is written in a nice, understandable style, in a nice, understandable style, in correct English. I also have no objections to its readability aspects.

From the dissertation's content, it is evident that the author demonstrated her proficiency in identifying a scientific problem, elucidated methods for its resolution, and substantiated the proposed methodology through experimentation. Furthermore, the PhD candidate has authored and co-authored several scientific papers with high impact factors strongly related with this dissertation topic. The author also added information regarding her participation in various projects, scientific cooperation and publications' record.

Also, the proposed research is very interesting and innovative. As mentioned above - the proposed solution allows any type of examination: CT, CT-PET, MRI, CT-PET-MRI and significantly affect the diagnostic process of brain glioblastoma. Nowhere in the literature have I been able to find an identically designed experiment using the methods proposed by the author, which includes also MRI data analysis besides CT and PET.

An attempt to write a thesis in a foreign language for a PhD student - English also deserves admiration and makes it available for widen audience of potential readers.

6. Negative aspects of the thesis - issues for discussion.

Ad. 6. Below my critical comments:
- A very short Conclusions chapter, which should be one of the main parts of the work.
- There is no discussion as a separate chapter, which would include a thorough comparison of all developed methods and a discussion of their properties.
- There is no comparison of the developed methods with other similar solutions (already existing and applied in clinical environments).
- The author did not compare classical methods with methods using deep learning.
- Why are results only shown for six patients?
- When and how would the doctoral student want to implement her solution?

7. Summary assessment.

Ad. 8. In this thesis, the PhD candidate has displayed a grasp of the research process. She was able to formulate and solve a non-trivial research thesis and design and develop novel and efficient algorithms. The overall work is very interesting.

The author of the dissertation speaks English fluently and is a co-author of very good (at this stage of her scientific career) scientific publications, which are strongly related with her doctoral topic. She took part in several very interesting research projects. In addition to her scientific activities, she has extensive experience in "industry" and has practical experience in field of computer science, which I consider very valuable and rare among scientists.

The thesis I had the pleasure of reviewing is very good, both the idea, the topic, the implementation and of course the results. It was very difficult to find any shortcomings in it, hence my critical comments are more inquisitive.

The overall conclusion about the thesis is **positive**. In my opinion, the doctoral dissertation of **mgr inż. Estera Kot** contains valuable research results and is an important scientific achievement in the development of scientific discipline: **Technical Information Technology and Telecommunications** (Informatyka Techniczna i Telekomunikacja).

I believe that this dissertation meets all the requirements for PhD theses and may be the subject of public defence.

I **recommend** the work of Mrs. **Estera Kot** for defence and I would like to apply for **distinction** of this dissertation.

Dr hab. inż. Aleksandra Kawala-Sterniuk, prof. PO