Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Ilias Giannakopoulos

PhD Program: Computational and Data Science and Engineering

Title of Thesis: Memory compression of the Galerkin volume integral equations and coil modeling for the electrical property mapping of biological tissue

Supervisor: Professor Maxim Fedorov

Date of Thesis Defense: 12 May 2020

Name of the Reviewer: Rykovanov, Sergey

I confirm the absence of any conflict of interest	Signature:
	(signature)
	Date: 20.04.2020

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

- Brief evaluation of the thesis quality and overall structure of the dissertation.

Thesis by Ilias Giannakopoulos is devoted to developing of novel methods for numerical modeling of electromagnetic phenomena for biomedical applications. The candidate shows excellent knowledge of the topic with an extensive and appropriate review given in the overall introduction and in the beginning of each chapter. Novel data compression methods based on tensor decomposition allowed the candidate to significantly speed up the calculation of the inverse electromagnetic problems using both CPUs and GPUs. The structure is well assembled, the thesis is well written, I only have minor comments and some additional questions more for my own education.

- The relevance of the topic of dissertation work to its actual content

Biomedical applications using electromagnetic waves (for example, body screening that can help cancer detection) are of great importance for the humankind. The computational problems that arise are very challenging due to several reasons: numerical volume (i.e. massive computational grids), ill-posed problems. Having a tool that can do the calculations fast, correct and effective is definitely an important development. This is exactly what is performed in research done throughout Ilias's thesis. The topic of dissertation is actual, interesting, challenging and definitely deserves to be reviewed and (successfully) defended.

- The relevance of the methods used in the dissertation

Main problems of the numerical solution of electromagnetic scattering are well identified already in the introduction of the thesis and later elaborated in details during the main part. Due to the single magnetic field frequency, one can use Helmholtz equation approximation to the full set of Maxwell's equations. In turn, one can then use the known Green's functions of the Helmholtz equation to turn the PDEs into the integral form and use methods like JVIE, DVIE etc. Later, in Chapter 4 where one of the main results are presented, Ilias applies tensor decomposition methods to speed up the VIE method. Methods used throughout the thesis are definitely relevant, not to say the only possible ones for the linear situation where magnetic field has only one frequency. I especially appreciated the usage of compression methods and transferring the simulations to GPUs.

- The scientific significance of the results obtained and their compliance with the international level and current state of the art

Healthcare is one of the most important areas to be considered. Siemens has recently upgraded their machines to have magnetic field with the strength of 7 Tesla which makes full body screening much faster and more precise. Results of the thesis will further help the scientist to make biomedical analysis faster and more precise. I think the results are significant, definitely deserving a PhD after successful defense. New numerical methods (especially compression of data, GPU usage and deep learning approach) presented in the thesis also have the potential to become commercial and licensed.

- The relevance of the obtained results to applications (if applicable)

As mentioned before, results obtained within this thesis are applicable in healthcare, which is very important and relevant in the modern days.
- The quality of publications
As far as I can tell, Ilias has 8 publications in peer-reviewed international journals, quality is definitely high.

The summary of issues to be addressed before/during the thesis defense:

1. List of abbreviations and notations is not complete, there are some abbreviations in the text that are not within this list. Moreover, there is such a number of abbreviations that it is really hard to read the thesis for the unprepared reader – you have to constantly go back and forth to the list to check what things mean. In future, I would advise to make texts more user friendly. This is a comment, which does not need to be addressed.
2. On page 3, there is a claim that "… MARIE and the MARIE 2.0 can produce reasonable EM field estimations in minutes." At this point it is not clear about the size of the object under discussion

and I believe the time estimate will change whether this is a finger of a full body. This can be adjusted.

3. On page 26, there is a sentence: "Regrettably, accurate solutions exist for perfect spheres…" This is a very bold statement and I would avoid such statement in texts. For example, without any comments given in the thesis I can immediately contradict this statement by saying that there are exact solutions for the case of a cylinder. This statement should be adjusted.

4. On page 26, there is a sentence about FDTD: "… solution is obtained with some preprocessing." Having been working with FDTD for years I do not really understand this statement yet. This should be extended and clarified.

5. Page 28, equation 2.38, does norm of 'a's have to be strictly larger than 0?

6. On the same page not all quantors are explained, for example in eq. 2.40.

7. Figures 3.7-3.10 there is a typo in Figures caption "Radiattion" and typos in the text: "Radiattion" and "azimuthail". "Azimuthail" also appears in text on page 48.

8. Figure 3.15, text is not readable at all, font size has to increase or some of the curves have to be removed. Caption and axes labels are also not readable.

9. Same for Figure 3.16

10. Merely nitpicking to make thesis perfect: In the reference list, the style of citations is not constant. Sometimes there is "Nature" and sometime "nature" (i.e. ref 121). Ref. 155 refers to a paper in German, so german spelling rules should be applied: " … zur Optik … Medien, … Metalloesungen", Annalen der Physik. This is a very minor comment that can be applied or not upon decision of the candidate.

Provisional Recommendation

☒ *I recommend that the candidate should defend the thesis by means of a formal thesis defense*

☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*

☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*