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Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis.

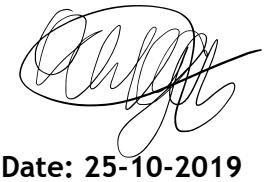
Name of Candidate: Ioannis P. Georgakis

PhD Program: Computational and Data Science and Engineering

Title of Thesis: FAST INTEGRAL EQUATION METHODS AND PERFORMANCE BOUNDS OF MODERN MAGNETIC RESONANCE COILS

Jury Member: Prof Ivan Oseledets

Name of the Reviewer:

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Signature:**  **Date: 25-10-2019**

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

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications

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

The presented thesis has 223 pages, introduction, 4 chapters, conclusion and 3 appendices.

It is motivated by a practical problem of coil arrays design for next-generation MRI scanners. When the magnitude of the field increases, such optimization plays a crucial role both for resolution and safety. The problem is reduced to coupled system of equations, which has both volume integral equation (VIE) inside the scatterer (biological tissue) and boundary integral equation (BIE) on coils. This is computationally challenging task, and also practically interesting. We need to measure the quality of the coils system somehow, thus the thesis introduces a new metric, (UITXE) which is a theoretical maximum of TXE that can be achieved for any physical setup. It can be computed as a solution of a generalized eigenvalue problem. The corresponding study should be interesting to practitioners. This is done by analytical methods, which have obvious limitations, i.e., for realistic head model. A fast VIE solver is introduced in Chapter 4. The solver is showed numerically to have a well-conditioned matrix. Another contribution is the usage of RSVD for compression for the coupled problem. Finally, the solver is used to test if the theoretical maximum can be achieved with finite coil arrays.

Comments:

1. The claim in the conclusion that solver is well-conditioned is not correct: the solver can not be well-conditioned, only the matrix of the linear system can be well-conditioned.
2. The claim that VIE can be solved by FFT for the uniform grid is known from the literature. (Section 6.1) and in the prior work. I do not understand what comes under the statement «We show that» in the contribution sections.
3. Personal contributions should be clearly stated and usage of «we» avoided. For example, section 5.2.2. describes the derivation of the generalized eigenvalue problem for computing the extremal case, but is it the contribution of the thesis?
4. The numerical experiment on a sphere shows O(h) convergence, not O(h^2). It seems like a drawback of the method. This should be commented.
5. What happens if the contrast in the media is large (with the solver?).

This comments do not change the overall evaluation of the high-quality and high-standard work by Ioannis. I recommend the thesis for defense.

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