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Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Maame Gyamfua Asante-Mensah

PhD Program: Computational and Data Science and Engineering

Title of Thesis: Automatic noise and artifacts removal from biomedical signals and images using tensor completion

Supervisor: Professor Andrzej Cichocki

Name of the Reviewer: Maxim Rakhuba, HSE University

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	 **Date: 29-05-2023**

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

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

The thesis is concerned with the development of new tensor decomposition techniques for noise and artifacts removal in biomedical data. From the mathematical viewpoint the thesis is devoted to the development of algorithms for solving different variants of the tensor completion problem, which is recovering unknown entries in a tensor by imposing low tensor rank constraints. Besides classical tensor completion formulation, the author of the thesis explores such techniques as hankelization transformation as a preprocessing step and additional regularization techniques that promote sparsity and smoothness.

Overall, the thesis is structured and well written. Chapters 1 and 2 are two preliminary parts that introduce background to the problem, notation and literature review with a good subject coverage. It is worth noting that overall notation is detailed and consistent along the thesis, which is important in the field of tensor decompositions. Specificity of biomedical data is also covered in these sections. Chapter 3 discusses different hankelization strategies as data preprocessing. In Chapter 4, a new method for tensor completion is presented. It combines data hankelization and additionally imposes sparsity of core tensors in a certain basis. Numerical experiments are performed on different kinds of data: images, MRI, time series and EEG signals. Chapter 5 considers application of cross approximation techniques to the tensor completion problem for fast and interpretable construction of approximations. Besides completion of images and MRI scans, the algorithms are also tested on video data. Finally, Chapter 6 contains a new algorithm that combines hankelization, tubal decomposition and ADMM method for MRI motion artifact correction.

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

I find that the topic of the dissertation and its content are relevant to each other.

The relevance of the methods used in the dissertation

The usage of tensor decompositions is relevant for completing missing data and removing noise in multidimensional arrays. Moreover, tensor completion algorithms are used in combination with hankelization data preprocessing, which is shown to give consistent improvements over the classical tensor completion approach. Other relevant techniques are also considered. For example, convolutional neural networks are utilized as a hankelization step to additionally boost the performance of tensor completion.

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

The candidate proposes three new methods in the context of tensor completion. One method explores sparsity in the cores of tensor ring decomposition and takes advantage of hankelization and dictionary learning. The second method is based on CUR-type approximation with smoothing constraints. The third method combines hankelization and tensor tubal norm for reconstructing motion artifacts from MRI. The conducted numerical experiments indicate that the proposed methods outperform or work on par with state-of-the-art tensor methods on the respective tasks, which justifies scientific significance of the

work. Also, the results in the thesis are based on publications of high quality in recognized international publication venues.

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

All developed methods are application oriented and can be useful in biomedical applications.

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

- Overall, the thesis contains references to many relevant works in the direction of tensor completion. However, the riemannian optimization approach is fully omitted. It would be appropriate to cite some classical works in this direction.
- In my opinion, the beginning of Ch. 4 should contain some motivation on why one should impose sparsity constraints for tensor cores.
- In Eq. (1.8) and later in Ch. 1.4, an undefined operation X_Omega is used instead of P_Omega(X) that is used in all other chapters.
- In (2.1) the min may not exist for the CP decomposition. Some comment about this would be appropriate.
- Eq. (2.2): either unfoldings of X or terms with Khatri-Rao product should be transposed. Otherwise the sizes are inconsistent.
- Alg. 4 and 5, page 46: data tensor should be of dimension N.
- Eq. (5.1) and related formulas: for the defined sizes CUR decomposition should read as CUR^T.
- Ch. 6 should be carefully reread to fix arising formatting, punctuation and grammar issues.

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*