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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: Alexander Bernstein

I confirm the absence of any conflict of interest	**Date: 19-05-2023**

Review

The dissertation work "Automatic noise and artifacts removal from biomedical signals and images using tensor completion" is written on an important and relevant topic, motivated by practical needs. Despite the existence of various mathematical and engineering methods for eliminating noise (including outliers) and artifacts removal from biomedical data (EEG and MRI signals), the problem remains relevant, and the presented work has demonstrated the possibility of further significant improvement of existing approaches and methods.

The dissertation as a whole is a systematic and high-quality scientific research. The structure of the dissertation corresponds to the essence of the research and allows to adequately present the results. The topic of dissertation work corresponds to its actual content.

The new and significant obtained scientific results of the dissertation were obtained through the use and development of modern mathematical methods based on matrix and tensor completion approach to the analyzing the considered signals, images and videos naturally represented by 3D/4D and, sometimes, higher-order tensors. Although various tensor completion techniques have already been developed, to date there are many known difficulties for their use in solving specific problems because many state of the available arts algorithms are slow with high complexity, provide poor performance when the number of missing elements is large or are only able to recover certain types of missing data such as randomly missing pixels. Motivated by such limitations of existing tensor completion techniques, new approaches, methods and algorithms were developed by exploiting and adopting different optimization strategies and constraints. Since the used existing and new methods developed in the dissertation made it possible to obtain significant scientific results and algorithms for solving applied problems, their use in the dissertation is justified.

In the thesis, new efficient approaches and algorithms for tensor completion task which are capable of removing artifacts and noise in biomedical data were developed. Proposed approaches are based on low-rank and high-order tensor decompositions techniques and constrained optimization methods that take into account the features of the considered problems (for example, imposing additionally sparsity or smoothness constraints) which are new for the considered applications.

New scientific results were obtained in the dissertation work consist in three new approaches and methods based on matrix and tensor network decompositions.

- First method is based on exploiting a sparse representation for tensor ring cores using dictionary learning has been developed. The proposed approach includes proposed and implemented an efficient procedure which allow to transform available data to higher order tensors and next estimate core tensors are estimated using tensor ring decomposition, as well a further generating the sparse codes with using an over complete discrete cosine dictionary and and their optimization (together with estimated core tensors) using the alternating Least Squares gradient descent algorithm. The proposed method provides higher performance compared to other completion methods.
- The second method proposed uses the matrix cross approximation methods and extends to the tensor case for 3D tensor completion. A smoothing technique is applied to the sampled incomplete fibers of each unfolding tensor before the tensor completion is performed. By applying the proposed method to structural data with missing components or high missing rate, the algorithms incorporates an efficient smooth variant of the developed tensor CUR algorithms, which first makes the sampled components smooth, and then the CUR algorithm is applied. This novel approach improves the performance of the completion results as compared to performing the completion without the smoothing strategy. Also the use of sampling of tubes of tensor reduces the running time of the method thereby providing a faster means of reconstructing huge incomplete data.
- The third proposed method performs reconstruction of motion artifact from diffusion weighted MRI images using Hankelization and tensor tubal norm. The developed algorithm employs the tubal norm of the tensor for reconstructing MRI images from few samples of K-space in the Fourier transform. The results are comparable to other methods used for reconstructing diffusion weighted MRI data.

Extensive computer simulations performed using all these three strategies show the effectiveness and superiority of the methods used in the research.

All studied tasks are motivated by applied biomedical requests, and obtained results have huge potential for solving practical biomedical problems. All results of the dissertation are fully published in prestigious specialized publications.

In general, the considered dissertation work was done on an important and relevant topic. It poses and solves important theoretical problems motivated by real biomedical applications. All the results obtained are new and have theoretical and practical significance.

Therefore, the dissertation work satisfies all the requirements for Ph.D. theses in the field of Computational and Data Science and Engineering, and its author Maame Gyamfua Asante-Mensah deserves to be awarded an academic degree.

Provisional Recommendation
[V] *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*