Dear Dr. Attila Kertész,

I would like to express my sincere gratitude for your thorough evaluation of my dissertation. Your insights have been invaluable in helping me to strengthen the clarity, depth, and overall quality of the work. Please find my detailed responses to your remarks and questions below.

1. What were the main differences in the properties of the synthetic and real datasets used to evaluate the proposed implementation, shown in Chapter 4?

The main difference in the properties of the synthetic and real datasets is whether their oscillatory components are known. In the synthetic dataset, these components are explicitly defined by mathematical formulas and are therefore used as ground truth to evaluate the numerical accuracy of different decomposition implementations. Specifically, the decomposition results from various implementations can be directly compared to the known components to assess correctness.

In contrast, the oscillatory components in the real EEG dataset are unknown and cannot be described mathematically. Consequently, the real EEG data is used to compare the computational performance of the different GPU decomposition implementations with the reference MATLAB implementation in realistic scenarios (128 channels, over 10-minute measurement duration). Additionally, it also enables us verify numerical correctness described by the Similarity Index.

2. Would a larger computing infrastructure help in gaining additional research results?

For GPU-based parallel implementations of EMD and its variants, a more powerful computing infrastructure offers significant advantages. Larger GPU global memory allows for processing longer data blocks in each load, which is particularly beneficial for long-duration EEG data. This reduces the frequency of data transfers between the CPU and GPU, thereby minimizing the overhead associated with memory swapping. Additionally, a more powerful computing infrastructure can provide access to more efficient and higher-performance processing cores. For example, next-generation, larger-scale tensor cores may provide new opportunities for further accelerating algorithms involving a large number of matrix multiply-add operations in EEG signal decomposition, like ICA.

Additionally, multi-node, multi-GPU computing systems hold considerable potential for large-scale EEG data analysis. EEG data from different study groups, subjects, trials, or even channels can be distributed across multiple nodes and processed in parallel, significantly improving computational efficiency and reducing overall processing time.

3. The Candidate stated that "achieving real-time EEG processing on wearable, low power portable devices is an ongoing challenge". Would the proposed solutions be usable in such real-time settings? What modifications would be needed, if not?

The proposed GPU-based solution is primarily designed to accelerate offline EEG data processing. However, the underlying parallelization approach and the data chunking strategy can serve as valuable references for real-time EEG signal processing. In the case of EMD and its variants, real-time processing is constrained by the algorithm's inherent requirement for signal segments, in order to detect extrema and perform interpolation. As a result, strict real-time processing is not feasible. Nevertheless, by leveraging data chunking and improving the handling of boundary effects in each chunk, existing GPU implementations can be adapted for online, near-real-time processing.

For ICA, the Online Recursive ICA (ORICA) algorithm [1] proposed by S. H. Hsu et al. enables online EEG signal decomposition from the algorithmic perspective. This method can be further accelerated using GPUs to enhance its real-time performance, making it a promising solution for practical deployment of real-time EEG analysis systems.

Reference:

[1] S. H. Hsu, T. R. Mullen, T. P. Jung, and G. Cauwenberghs, "Real-Time Adaptive EEG Source Separation Using Online Recursive Independent Component Analysis," *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 24, no. 3, pp. 309–319, Mar. 2016, doi: 10.1109/TNSRE.2015.2508759.

Thank you once again for taking the time to review my dissertation. I will carefully consider the other suggestions you provided, revise my dissertation accordingly, and give you feedback as soon as possible.

Veszprém, 4 July 2025

Zeyu Wang

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