A System for the Online Reconstruction of Distributed Sources from EEG and MEG data

Mirco Fuchs[1,2], Christof Pieloth[1], Jorge M. Pizarro[1], Thomas R. Knösche[2], Burkhard Maess[2]

[1]HTWK Leipzig, University of Applied Sciences, Laboratory for Biosignal Processing, Eilenburger Str. 13, 04317 Leipzig, Germany
[2]Max Planck Institute for Human Cognitive and Brain Sciences, Stephanstr. 1a, 04103 Leipzig, Germany

fuchs@labp.htwk-leipzig.de

Introduction

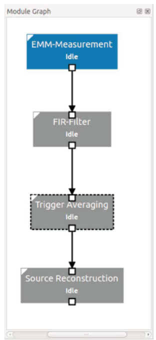
Neuroelectromagnetic signals given by EEG/MEG measurements provide an excellent time resolution of underlying brain processes. A common method to localize brain activity is distributed source reconstruction, particularly in case of analyzing event related potentials. Such analysis requires several preprocessing steps, e.g. artefact detection and correction, filtering, epoch separation and averaging, and is usually performed offline. Online source localization would provide the visualization of brain activity during the measurement, which is interesting for both medical and research applications. We developed a concept that allows to set up and tune an online signal processing chain, including distributed source localization on individual head models. The implemenation is based on OpenWalnut, a software dedicated to multimodal brain visualization [1,2]. The capabilites of online processing were tested based on streaming a previously recorded dataset and measuring the execution times.

Methods

Based on the blockwise streaming of a previously recorded real data set, we revealed the principle time behaviour and online processing capabilities of the system. Fig. 3 shows the signal chain that was used for testing purposes.

- Data set: 80s EEG/MEG data @ 500Hz, auditory stimulus (120 trials), 60/306 channels, Source- and head model extracted from FreeSurfer, Leadfield computed using SimBio (244662 sources, 3 layer BEM, only for EEG)
- EMM Modul: 1s blocksize
- FIR Filter: 1Hz - 20Hz bandpass, order 200
- Trigger Averaging: Epoch -100 ... +200ms, total average
- Source Reconstruction: MN method,SNR=5
- Execution: 2 test cases (only CPU/GPU processing), 240 blocks processed for each case
- Hardware: NVIDIA Tesla C2070 GPU, Intel Xeon E5620, 2.4 Ghz CPU
- Mean execution time per module/algorithm/CUDA kernel was estimated

3 Module Graph

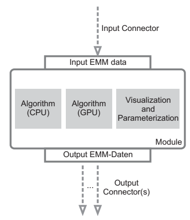


Signal processing chain used to simulate online distributed source reconstruction.

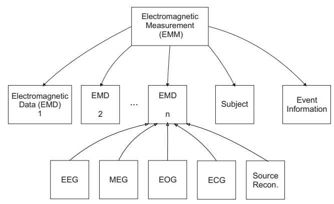
Concept and Implementation

We used a modular implementation concept, where each algorithm, i.e. stage in the signal processing chain, is realized in a distinct functional unit, e.g. a module (Fig. 1). A parameterization and visualization interface is assigned to each module. Within a module, an algorithm can either be executed on the CPU or on a GPU. Before starting the measurement, a signal chain can be set up by combining several modules, which is provided by input and output connectors. To some extend it is even possible to tune parameters and insert additional processing stages during a measurement. Further, it is possible to assign the output of a module with the input of several following modules, which basically allows to run different signal processing chains concurrently. Data between modules is shared using the data structure given in Fig. 2, where the actual time dependent data is transfered blockwise based on a parameterizable block size. The top level class, Electromagnetic Measurement, combines all subsequent data structures that are necessary for online processing. It consists of at least one electromagnetic data (EMD) structure, each of which represents a collection of channels that belong to a certain electromagnetic signal type, e.g. EEG or localized data, and a subject modul that contains the individual head model, other subject specific information and, at the moment, a previously computed forward solution. Based on this concept, we realized the modules a) EMM Measurement, where either a recorded measurement can be loaded or simulation data can be generated and which realizes the blockwise streaming, b) FIR Filter, c) Trigger Averaging, which implements epoch separation and averaging and d) Source Reconstrucion, which performs distributed source localization.

1 Structure of a Module



2 Data structure shared between Modules



Results

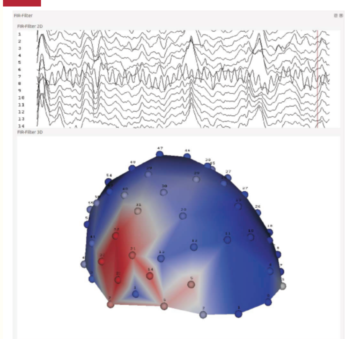
Whenever a new data set is received at the module input, it will be immediately processed. Processing the signal chain completely during the time range defined by the streaming block size was only possible when executing the algorithms on the GPU (Fig. 4). Especially for source reconstruction the improved performance when using the GPU is noteworthy. The time for the initial calculation of the inverse minimum norm operator was 2.2s on average. However, its recalculation during a measurement is only rarely necessary. Like the FIR Filter, Fig. 5, each module has its own view, where it can be configured and where the calculation results are visualized. While raw and filtered data is streamed through the 2D view, epochs and averaged data are shown statically (Fig. 6).

4 Mean Execution Time

Module	CPU	GPU
FIR Filter	85.6 ms	31.2 ms
Trigger Averaging	5.7 ms	
Source Reconstruction	1415.5 ms	129.8 ms
Total	*1506.8 ms*	*166.7 ms*

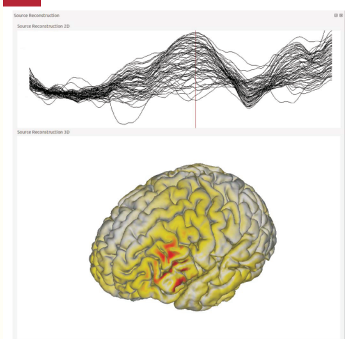
The times represent the mean duration for processing one block including all EEG and MEG channels in case of the FIR Filter and Trigger Averaging module, and one (averaged) epoch including all EEG channels in case of the source reconstruction module. If data is processed on the GPU (only implemented for filtering and source localization), the total execution time is much shorter than the blocksize (1s), which is mandatory for online processing.

5 FIR Filter



The view of the FIR module shows both a filtered (EEG) data block (top) and the potential distribution at a selected time point (bottom). Data is smoothely streamed through the 2D view.

6 Source Reconstruction



Source reconstruction based on EEG data after 120 trials. 2D view (top): averaged data, 3D view (bottom): source strengths mapped to the cortical surface at a selected point in time.

Discussion

In principle, the presented solution can be used to process EEG/MEG data online, i.e. during a measurement, including distributed source localization. While the processing time will be slightly increased when source localization is extended to MEG data, we still expect a significant gap to the blocksize, which defines the soft realtime requirements of the system. Further, while the localization is currently done for all samples of the averaged data, which is not necessarily needed, there are still some possibilities to optimize the processing chain. This is important, because further algorithms will be necessary to increase the quality of source localization, e.g. artefact rejection/correction and head movement correction in case of MEG measurements. Even methods that operate in the source domain could be used to extend the system. An important issue is the calculation of the forward solution, which is required to be present when starting online processing, however sensor positions (EEG) or the head position (MEG) is only available directly at the begin of the measurement. It is part of current work to overcome this problem, e.g. using leadfield interpolation in case of EEG processing.

References

[1] S. Eichelbaum, M. Hlawitschka, A. Wiebel, *OpenWalnut - An Open-Source Visualization System*, Proceedings of the 6th High-End Visualization Workshop, 2012

[2] S. Eichelbaum, M. Goldau, S. Philips, A. Recihenbach, R. Schurade, A. Wiebel, *Open Walnut: A New Tool for Multi-modal Visualization of the Human Brain*, EG VCBM 2010

FKZ 17108X10
profUnt
Forschung an Fachhochschulen mit Unternehmen
Bundesministerium für Bildung und Forschung