Tensor-based Hemodynamic Response Estimation in Functional Ultrasound Data

Kotti, S.E.; Hunyadi, Borbala

Publication date
2022

Document Version
Final published version

Published in
42nd WIC Symposium on Information Theory and Signal Processing in the Benelux (SITB 2022)

Citation (APA)
Kotti, S. E., & Hunyadi, B. (2022). Tensor-based Hemodynamic Response Estimation in Functional Ultrasound Data. In J. Louveaux, & F. Quitin (Eds.), *42nd WIC Symposium on Information Theory and Signal Processing in the Benelux (SITB 2022)* (pp. 69)

Tensor-based Hemodynamic Response Estimation in Functional Ultrasound Data

Sofia-Eirini Kotti
Circuits and Systems, EEMCS
Delft University of Technology
Delft, The Netherlands
S.E.Kotti@tudelft.nl

Borbála Hunyadi
Circuits and Systems, EEMCS
Delft University of Technology
Delft, The Netherlands
B.Hunyadi@tudelft.nl

ABSTRACT

Functional ultrasound (fUS) is an emerging technique that provides high sensitivity imaging of cerebral blood volume (CBV) changes. As increased metabolic demand of active tissue induces changes in CBV, these changes reflect neuronal activity in the corresponding brain area. The main advantages of this technique are that it can image the entire brain with unprecedented spatial (50-500um) and temporal resolution (10-100ms), and that it constitutes a potentially portable solution, as opposed to functional magnetic resonance imaging (fMRI), the currently dominant modality in functional brain imaging. The high resolution as well as the plane-wave illumination lead to a large amount of raw ultrasound data per aquisition.

The fundamental challenge is that fUS only provides an indirect measure of brain activity through the neurovascular coupling; this system is the link between the local neuronal activity and the resulting blood flow changes and has only partially known dynamic and nonlinear characteristics. Moreover, besides the activity of interest, fUS records a mixture of other ongoing brain activity, physiological artifacts and noise.

The goal of this research is to develop tensor-based source separation techniques in order to estimate the brain's hemodynamic response function (HRF) to stimuli and the activity of interest by learning its nonlinear coupling with the fUS signal. Tensors are a natural mathematical representation of the obtained fUS data; e.g. 2D images over time, or 3D images over time or across different subjects. The specific challenges to solve include:

- Characterizing the HRF in terms of a (non)linear parametric model,
- Adapting functional image processing techniques so that they can (a) act on high-dimensional data, exploiting the low-rank property of the images, (b) incorporate a parametric model of the HRF and (c) perform efficient joint decomposition of multiple images that are not acquired simultaneously but pairwise share spatial characteristics,
- Improving the preprocessing stage of the tensor data: current clutter-filtering techniques based on the singular value decomposition act on unfolded (matricized) data, destroying the spatial dependencies between neighboring voxels in the images.