Toolbox for enhanced fMRI activation mapping using anatomically-adapted graph wavelets

Hamid Behjat[1*], Leif Sörnmo[1], Dimitri Van De Ville[2,3]

1. Biomedical Signal Processing Grroup, Dept. of Biomedical Engineering, Lund University, Sweden
2. Institute of Bioengineering, École polytechnique fédérale de Lausanne, Switzerland
3. Dept. of Radiology and Medical Informatics, University of Geneva, Switzerland

LUND UNIVERSITY

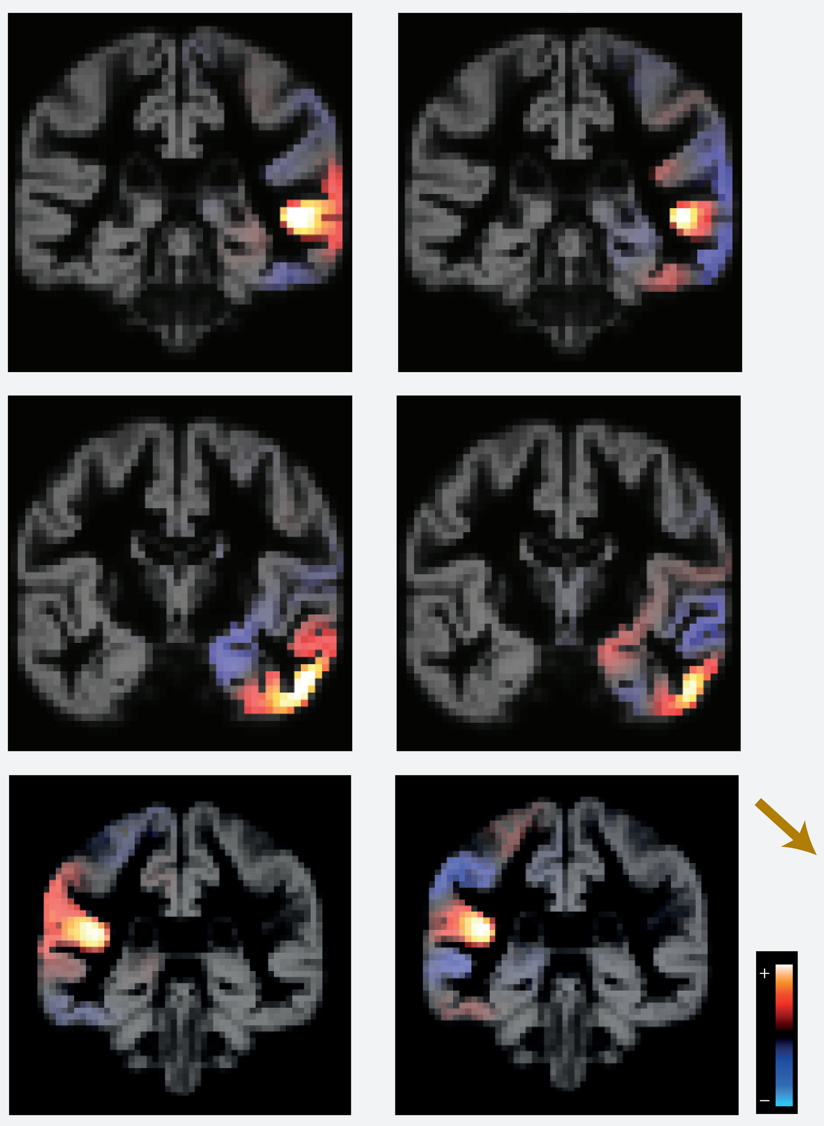
graph-based
gwSPM
wavelet-based

The method

Abstract

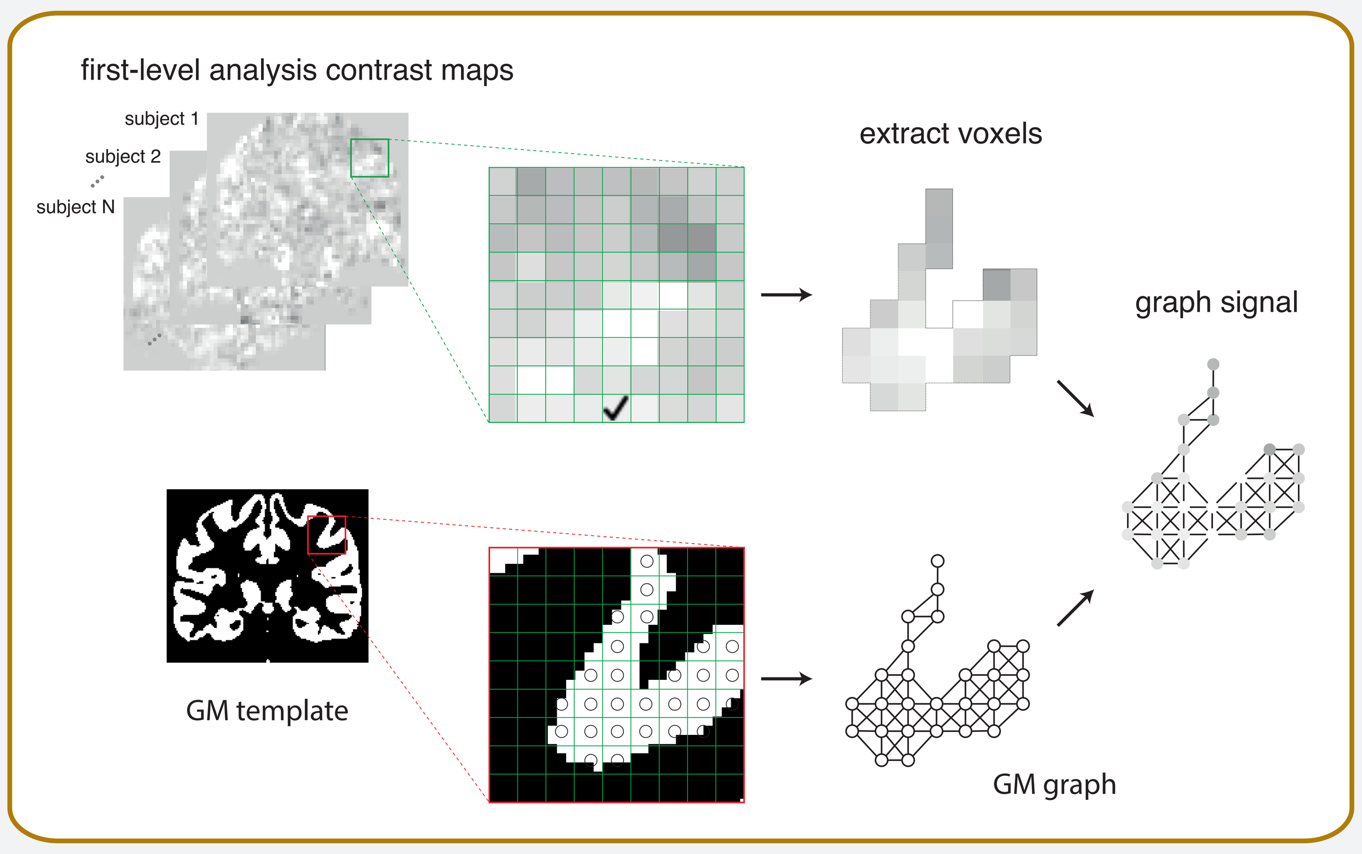
In fMRI studies with evoked activity, brain activity is detected by voxel-wise GLM fitting, followed by statistical hypothesis testing. Statistical parametric mapping (SPM), one of the most popular classical methods, relies upon Gaussian smoothing to deal with the multiple-comparison correction. As an alternative, we have recently introduced a graph-based framework for fMRI brain activation mapping [1]. The graph is designed such that it encodes the topological structure of the gray matter (GM). The approach exploits the spectral graph wavelet transform [2] for the purpose of defining an advanced multi-scale spatial transformation for fMRI data. The use of spatial wavelet transforms has the benefit of providing a compact representation of activation patterns. The framework extends wavelet-based SPM (WSPM) [3], which is a framework that combines wavelet processing of non-smoothed data with voxel-wise statistical testing while guaranteeing strong FP control. Here, we present an implementation of the proposed framework as a user-friendly, SPM-compatible toolbox that deals with multi-subject studies.

Anatomically-adapted graph wavelets*



* wavelet = a spatially localized function

Mapping an fMRI contrast map to a graph signal



Realizations of six wavelets that are adapted to the topological structure of the gray matter is illustrated. For ease of visual interpretation, the wavelets are overlayed on a template gray matter. Note that the wavelets are constructed in 3D space, and diffuse in 3D space, but only a single coronal slice of each is displayed.

The wavelets shown in each row are centered around the same location in the gray matter, the ones on the left have a smoother spatial profile compared to the ones on the right. A distinct set of wavelets is constructed for each location in the gray matter, but those of only three locations are displayed here.

The toolbox

Inputs to the algorithm:
T1 structural scans & first-level analysis contrast maps for a set of subjects.
The data for each subject should be co-registered.

step 1 — Gray matter (GM) template construction

step 2 — Construction of a whole brain GM graph & graph signals

The graph consists of two subgraphs that separately encode the structural connectivity of the cerebral and cerebellar GM.

The graph signals are constructed from first-level contrast maps after their normalisation to the template space.

step 3 — Second-level analysis with SPM

Input: first level contrast maps that were normalised to the defined template domain.

Output: the resulting SPM.mat is used in the following steps.

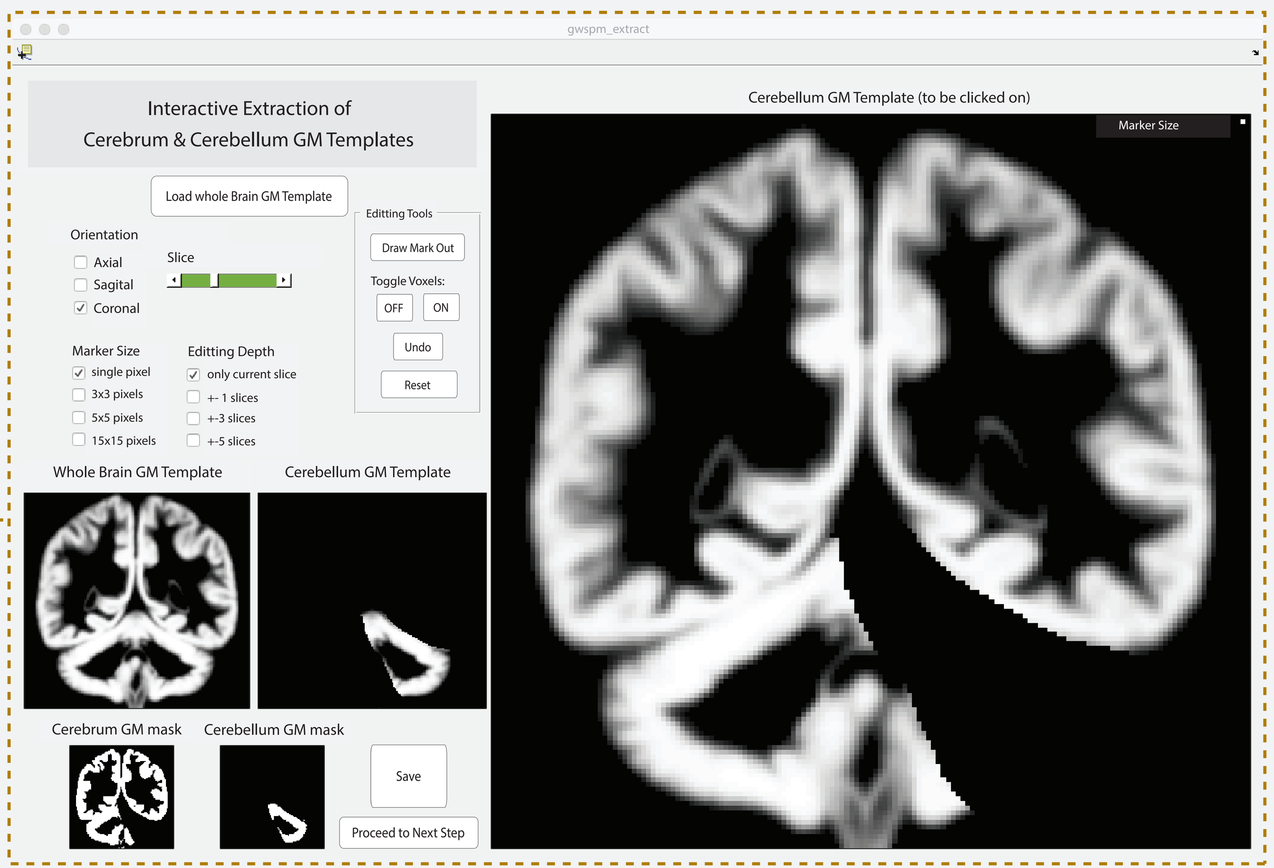
step 4 — GM-adapted wavelet transform design & decomposition of data

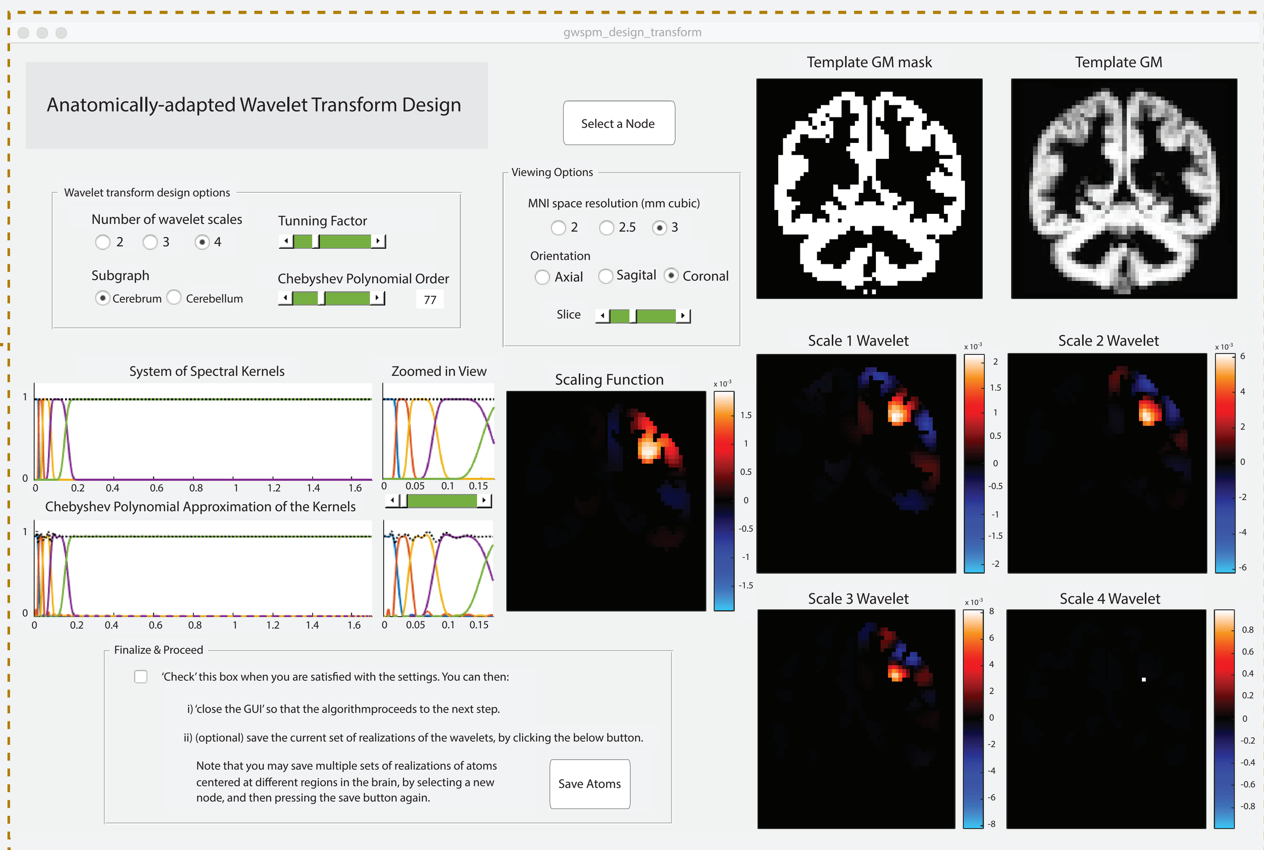
User interaction features:
tunning of graph wavelet design; construction & visulazation of realizations of wavelets at different scales, centered at different locations in GM.

step 5 — Integrated wavelet denoising & spatial statistical testing

The wavelet denoising and statistical inference method used in this step is based on the theory developed in [3].

step 6 — Display of results





Toolbox download

miplab.epfl.ch/software/

Contact

hamid.behjat@bme.lth.se

References

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[2]. D.K. Hammond, et al., "Wavelets on graphs via spectral graph theory." Appl. Comput. Harmon. Anal. 30(2), 129-150,2011.
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