fMRI activation mapping using wavelet-based SPM (WSPM) integrated with gray-matter graphs

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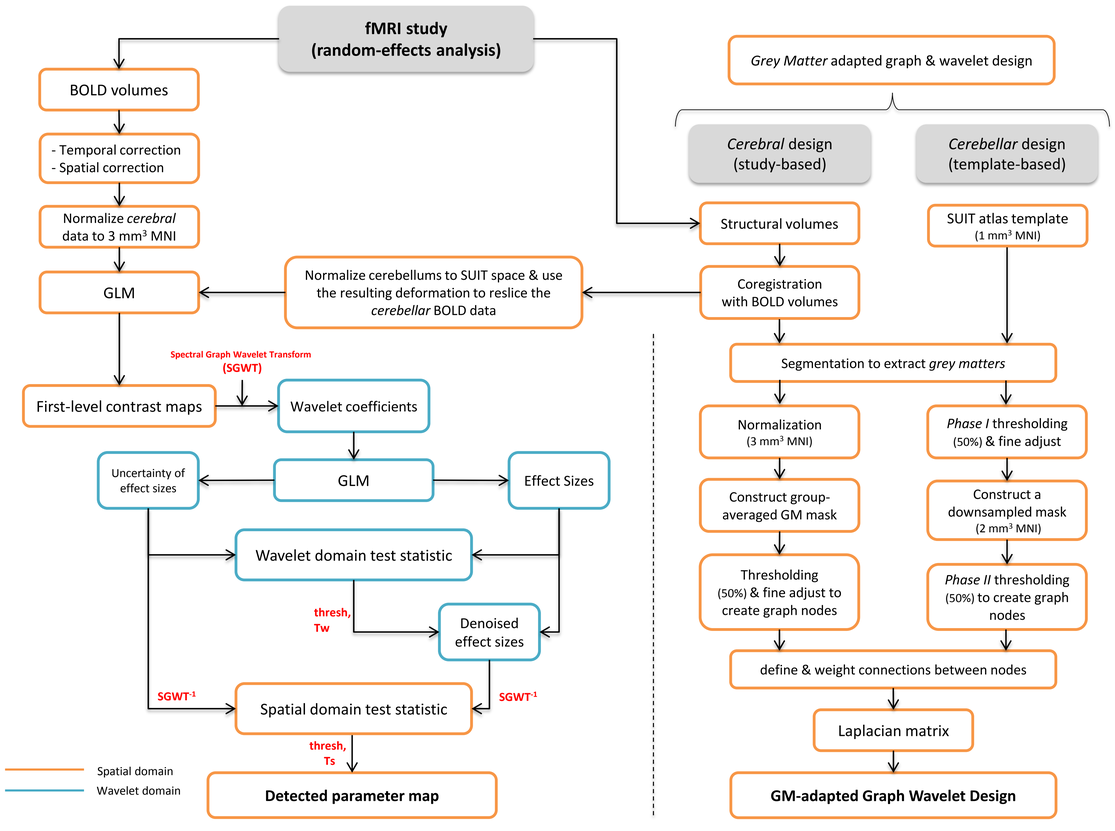
Abstract

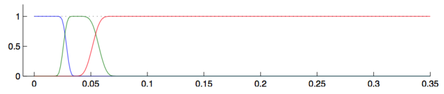
In many fMRI task-evoked studies, localized brain activity can be detected by GLM fitting and statistical hypothesis testing. Statistical parametric mapping (SPM) is the classical method that requires Gaussian pre-smoothing of the data. Instead, the wavelet transform provides a compact representation of activation patterns. Wavelet based SPM (WSPM) (3) is an extension of SPM that combines wavelet processing with voxel-wise statistical testing. However, classical wavelets used in WSPM are designed for regular Euclidean grids and thus not adapted to the convoluted nature of the cerebral cortex. We recently showed how WSPM using graph wavelets tailored to the gray-matter structure of the cortex (sgWSPM) can improve detection of brain activity in single-subject studies (1), and also illustrated the design and applicability of a canonical set of cerebellar graph wavelets for analyzing cerebellar data (2). Here we show the extension of this approach to *group-level* analysis by considering a brain graph consisting of two subgraphs: a *group averaged* GM-based graph of the *cerebral* region and the proposed *template* cerebellar graph (2), which enables the design of GM-adapted wavelets that use basis vectors of each subgraph.

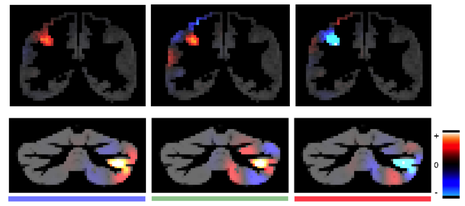
Methods



Results

Grey matter adapted wavelet design

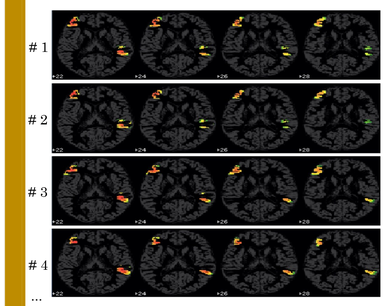




Note that the wavelets diffuse within 3D space but we here only illustrate an image of a coronal slice overlaid on the group averaged GM mask and SUIT template GM for the cerebral and cerebellar regions, respectively.

Simulation results

Simulated two activation patterns with 16 slightly different realizations to simulate inter-subject variability, and corrupted with additive Gaussian noise.

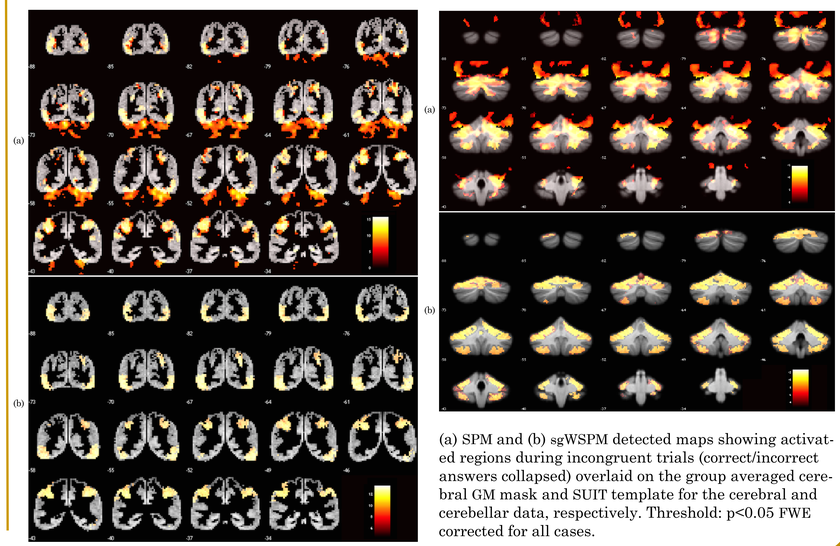


	SPM (6mm)	SPM (8mm)	WSPM	sgWSPM
# of detections	889	1261	727	829
GM50	727	899	573	n/a
TP	638	778	493	772
FP	251	483	234	57

# of active voxels	2110
# of active voxels with average activity > 0.5	1099

Experimental results

26 subjects performed an event-related Eriksen flanker task. The task consisted of indicating the direction of a central arrow, which was surrounded by arrows of the same (congruent) or opposite direction (incongruent trial).



(a) SPM and (b) sgWSPM detected maps showing activated regions during incongruent trials (correct/incorrect answers collapsed) overlaid on the group averaged cerebral GM mask and SUIT template for the cerebral and cerebellar data, respectively. Threshold: p<0.05 FWE corrected for all cases.

Conclusions

- Exploited recent advances in graph wavelets for statistical analysis of fMRI data and proposed an extension to analyze data at the group level.
- Designed a group-level graph by using the segmented GM of all subjects as well as a cerebellar atlas template.
- The approach enables a spatial adaptation to the underlying anatomy where brain activity is expected to lie, and encodes brain activity at fine scales thanks to the multi-scale property.

Outlook

- Brain functional connectivity analysis
- Spectrum-adapted graph wavelet design

References

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