Spatial Regularization for fMRI Detection

National Alliance for Medical Image Computing

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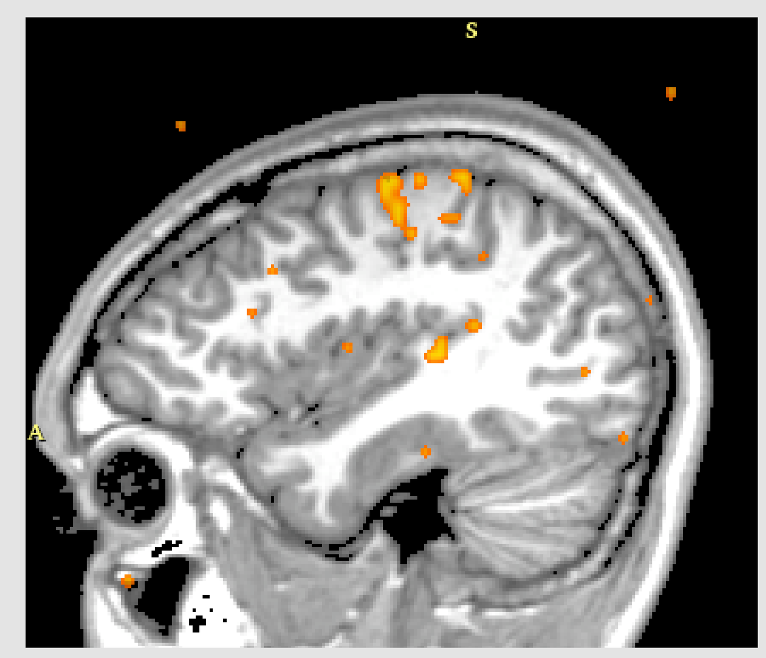
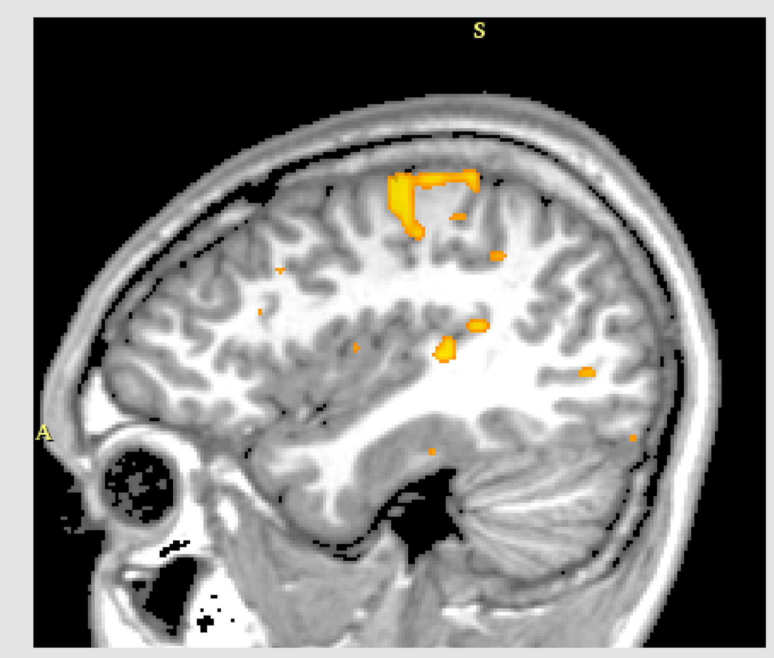
Summary

We have developed a method for brain activation detection that employs Markov Random Fields (MRF) as spatial smoothing priors necessary due to the low signal-to-noise ratio of the fMRI signal. Furthermore, we extended the MRF prior to include anatomical information. The anatomical prior, in the form of a segmented MRI scan, biases the activation detection towards the gray matter and inhibits smoothing of the activation maps across tissue boundaries. We have validated the method on a set of digital phantoms and a set of fMRI scans.

We are currently translating this work into 3D Slicer, an open source medical image analysis and visualization package developed and supported by Core2 activity, and are exposing the functionality through Slicer's fMRIEngine module.



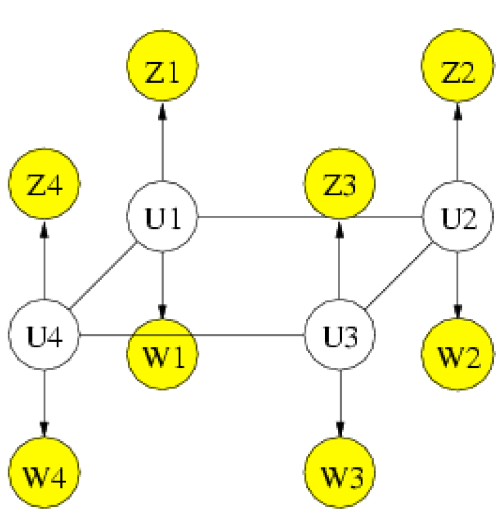
Without Spatial Regularization



With Spatial Regularization

Algorithm

- The spatial regularization methods are incorporated into the GLM detector
- Markov priors for activation
  - Capture spatial dependency in activation
  - Overcome over-smoothing effect compared with Gaussian smoothing
- Anatomical information (segmentation) provides further regularization
  - Activation is more likely in the gray matter
  - Spatial dependency is strong within the same tissue, but weak across tissues



Z_i: GLM Statistic for voxel *i*

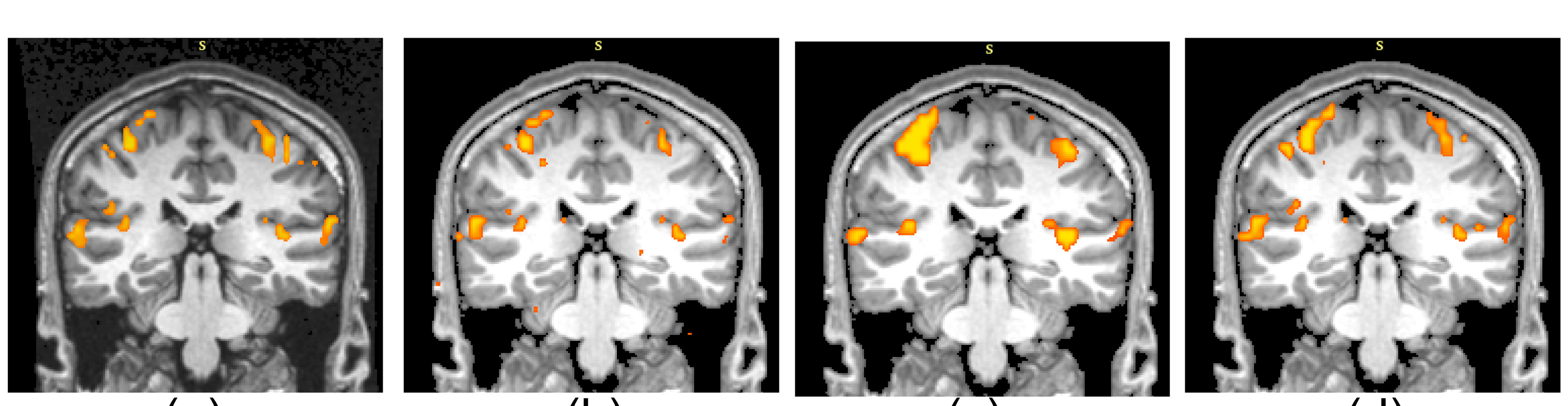
W_i: Segmentation label for voxel *i*

U_i: True but unknown activation state and tissue type for voxel *i*.

Output of our algorithm: posterior probability of U_i.

Results

- Synthetic fMRI Data, ROC Analysis
  - MRF outperforms Gaussian smoothing at realistic noise levels
  - Guassian smoothing is superior at higher noise levels
  - Anatomical information can further improve detection accuracy.
- Real fMRI Data, Visual Comparison of the Activation Maps
  - Increase detection accuracy with reduced-length signal



(a) (b) (c) (d)

(a) Activation map generated using full-length fMRI signals

(b-d) Activation maps generated using the first 1/3 of the signals:

(b) without spatial regularization.

(c) with 6mm-FWHM Gaussian smoothing

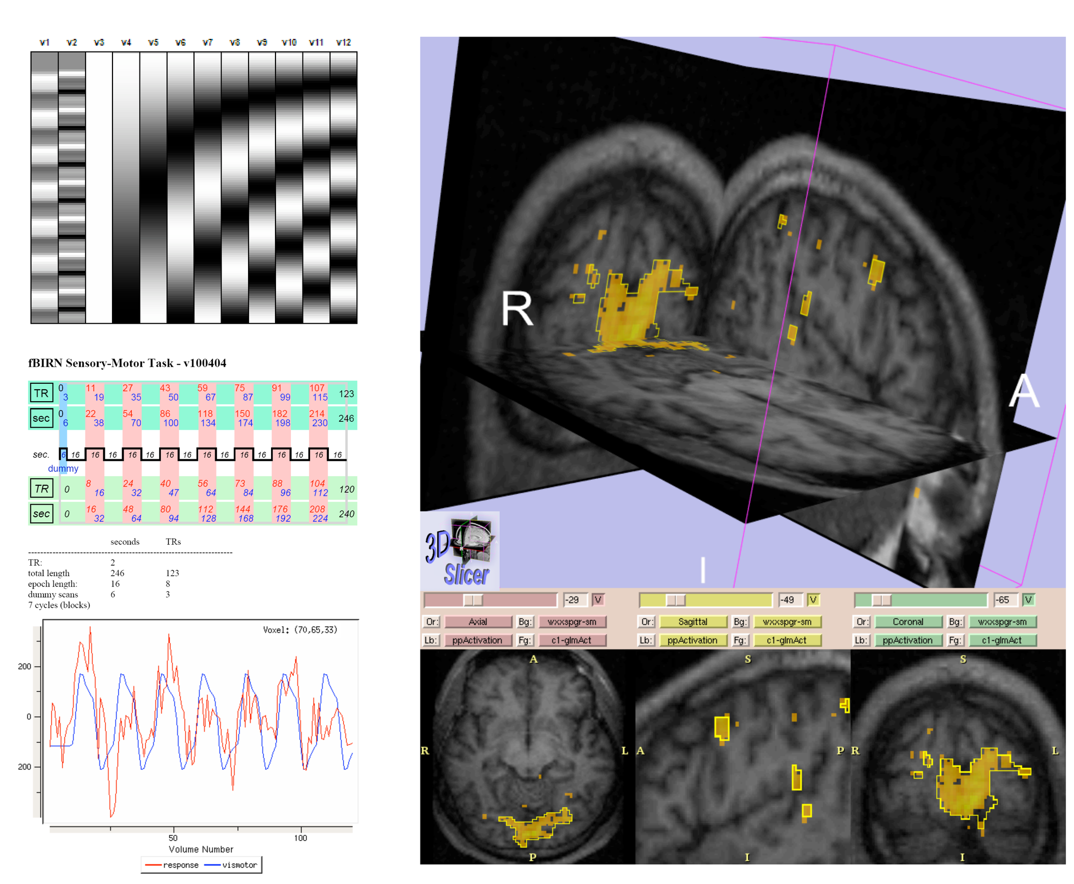
(d) with anatomically-guided MRF spatial regularization

Open source implementation

MRFs with optional support for spatial prior models are being implemented in 3D Slicer.

fMRI analysis: Design matrix, stimulus schedule, and voxel timecourse plot of a strong responder are shown (below) for a visuomotor (finger tapping) task.

Visualization: Resulting parametric map of brain activation computed using GLM detector is shown as transparent overlay along with outline of MRF output; analysis and visualization from 3D Slicer's fMRIEngine module.



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