Realistic Internet-available phantoms for evaluation of fMRI Processing Software

Y. Li[1], V. Morgan[2], D. R. Pickens[2], B. M. Dawant[1]
[1]Department of Electrical Engineering and Computer Science, Vanderbilt University, Nashville, TN, United States, [2]Department of Radiology and Radiological Sciences, Vanderbilt University, Nashville, TN, United States

Introduction

A number of fMRI processing packages have been developed to analyze fMRI data but it is often difficult to assess how well these approaches perform on a real study because of the lack of gold standards. Computer-generated phantoms have been used to compare these post-processing protocols [1]-[3] but these are typically not broadly available. In this work we generated a group of phantoms with realistic motion artifacts, simulated activation patterns, and various SNRs. To permit others to evaluate their activation analysis methods, these phantoms can be downloaded through our web site[1].

Methods

An overview of the phantom construction process is shown in Figure 1. All phantoms are generated based on a single template. This template is a noise-free fMRI sequence without motion or activation. It was created by selecting an image volume of 19 slices from one of the fMRI studies, de-noising this volume using a wavelet-based algorithm [4], and reproducing it 99 times to get the template. All motion models were estimated from real fMRI studies performed under controlled conditions. In these studies, following instructions, subjects were asked to move during acquisitions according to four different scenarios: low motion uncorrelated and correlated with the activation model, and high motion uncorrelated and correlated with the activation model. Using a combination of rigid and non-rigid intensity-based registration algorithms [5], all the images in each time series were registered to each other. The transformations computed with this technique served as an estimator for the motion occurring during the scan. Next, these estimated motion models were registered to the template using the same registration algorithms mentioned above. Ten activation regions with different signal amplitudes were added to the template based on a block design paradigm. Slice scan time difference were also modeled. The registered motion models were subsequently applied to the template. Finally, Rician noise of varying magnitude was added to study the effect of the SNR on the fMRI activation detection algorithms.

All types of phantoms, as well as the parameter files used to create the phantoms, are placed on an ftp server that can be publicly accessed through a web interface. Each phantom is formatted as a concatenation of all image volumes in the time sequence, with size 64x64x19x100x2 bytes (about 15MB, uncompressed). Parameter files for each phantom include rigid motion parameters, location of active regions and levels, and activation time course.

Results

A total of 40 different phantoms, created with the four types of motions described above and four SNRs, have been generated at the time of this writing. Figure 2 shows the activation regions detected by SPM2 in one of our low correlated motion phantoms with a low SNR.

Conclusions

Phantoms with realistic motion models estimated from a series of real data sets have been generated and are available for public access. Deformation fields and activation patterns that have been used for the generation of the phantoms are also available. These data sets will permit the evaluation of algorithms and software packages designed for the analysis of fMRI images. Further improvements to our current setup include creating phantoms interactively by adjusting parameters through web interfaces.

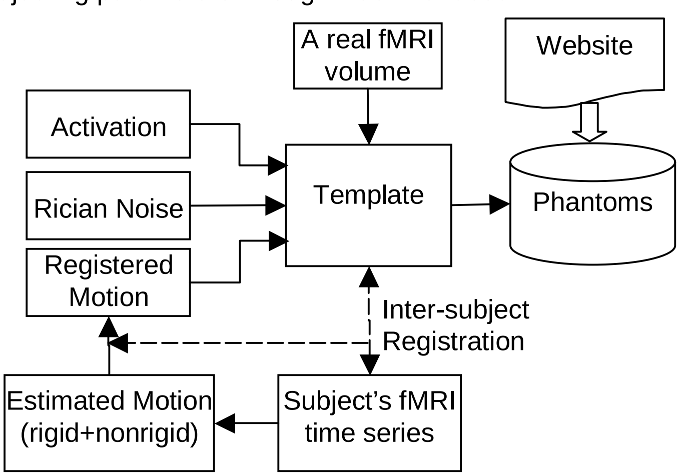

Figure 1 A Overview of Phantom Generation

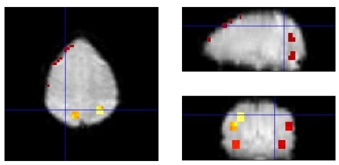

Figure 2 A low correlated phantoms with low SNR, true and false activations detected by SPM2

References
[1] Skudlarski P, et al., NeuroImage 1999; 9:311-329
[2] Ardekani BA, et al., *Magn.Reson. Imag.*2001;19:959-963
[3] Morgan VL, et al., *Magn. Reson. Med.* 2001; 46:510-514
[4] Robert D. Nowak, *IEEE Trans. Image Processing,* vol. 8, no. 10, pp. 1408-1419, 1999
[5] G.K. Rohde, et al., *IEEE Trans. Medical Imaging,* vol. 22, no. 11, pp. 1470-1479, 2003

This work was supported by the NIH grant R01-NS46077.

[1]http://www.vuiis.vanderbilt.edu/fmriphantoms