

Detection of BOLD fMRI Signals Using Complex Data

SONG LAI, G.H. GLOVER
Lucas MR Center, Department of Radiology
Stanford University, Stanford, CA 94305-5488

Introduction

The majority of fMRI studies obtain functional information using only magnitude images. Although magnitude detection of complex MRI images has the advantage that it is immune to the incidental phase variations arising from various sources [1], important functional information is often encoded into the NMR phase images, and is not detectable with magnitude image. In this abstract, we propose the use of complex data to create functional maps.

Methods and Materials

Algorithm A complete MR image is essentially a complex one, i.e., $I = x + i*y$, where $x = \text{Re}(I)$ and $y = \text{Im}(I)$ are the real part and the imaginary part of the complex image I , respectively.

With a typical time series acquisition, i.e., N time frames consisting of several cycles of alternating activation task off and on periods, a complex activation map is obtained by calculating cross-correlation coefficient, cc , on a pixel-by-pixel basis as follows:

$$cc = \frac{\{[\sum(x - \bar{x})(r - \bar{r})]^2 + [\sum(y - \bar{y})(r - \bar{r})]^2\}^{1/2}}{(N-1) \sigma_r \sqrt{\sigma_x^2 + \sigma_y^2}}$$

where r is time-dependent periodic reference signal that has the same period as the activation task on/off cycle, σ 's are the standard deviations over the time series. The range of value for cc is between 0 and 1. Specifically, we used sinusoidal functions (sine and cosine) as reference functions [2].

MR data acquisition MR experiments were performed on a GE 1.5 T whole body MR system equipped with high performance gradients (SIGNA, rev. 5.5: 22 mT/m, 120 mT/m/ms; General Electric Medical Systems, Milwaukee, WI). Motor cortex activation time series images were obtained by running a 3D spiral sequence. The 3D spiral sequence was developed by adding Fourier phase encoding gradients to the slice select direction of a conventional 2D spiral sequence. The imaging parameters are: 8 contiguous slices of 3mm thickness, TR 80ms, TE 40ms, FA 25°, FOV 240 mm, 4 spiral interleaves in the k_x - k_y plane, 100 time frames were collected in 256s with the resting state and the activation state being alternated every 20s. The subject was instructed to remain relaxed in the resting state, and to perform self-paced, consecutive and repetitive finger tapping of the right hand in the activation state.

Image reconstruction Image reconstruction involves Fourier transformation in the slice select direction followed by regridding of the spiral k -space data onto a Fourier grid, correction of the apodization effects of the Kaiser-Bessel convolution window, and correction of blurring effect resulting from off-resonance. Navigator echo technique was used to further reduce artifacts arising from intra-image phase variations. Real part images and imaginary part images were obtained by Fourier transformation. Magnitude images and NMR phase images were also reconstructed in order to demonstrate the characteristics of the activation maps using complex data.

Results

Time series correlation using complex data detected significant activation signals in the contralateral motor cortex areas. More importantly, these activation maps contained extra activation signals than the activation maps using magnitude images only. Careful examination confirmed that these extra signals were seen in the activation maps using the NMR phase time series. Figure 1 are the overlaid activation maps of one 3D slice, where activated pixels were defined using both correlation coefficient thresholding ($cc \geq 0.3$) and spatial extent thresholding (a cluster size of 5), representing a significance level of $p < 0.01$ [3].

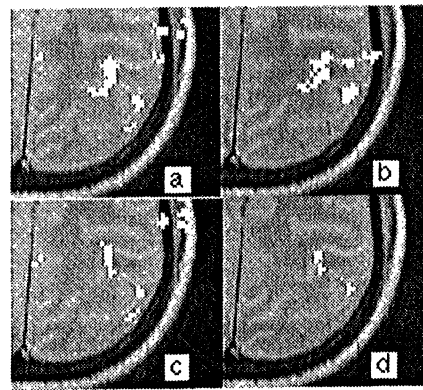


Figure 1. Right hand finger tapping activation maps from complex data (a), magnitude detection (b), and NMR phase detection (c), respectively. The bright pixels in Fig. d are seen in both the magnitude detection (b) and the phase detection (c), most likely delineating large veins [2].

Discussion and Conclusions

Detection of BOLD fMRI signals using complex data is superior to the conventional magnitude detection. Activation maps from complex data essentially integrate functional information from both magnitude and NMR phase detection. The activated pixels detected by both the magnitude images and the NMR phase images are believed to contain large venous blood volume fraction [2], consistent with the fact that these pixels were seen as dark spots in the magnitude images (i.e., paramagnetic deoxyhemoglobin-induced susceptibility effects). Therefore, the above method represents an efficient approach to localizing large veins in BOLD fMRI studies. Compared with the approach to collect additional flow-sensitized images to visualize large vessels, our method can reliably discriminate large veins without worry about possible inter-scan patient movement.

This work was supported in part by NIH grant P41 RR09784, and Lucas & Baxter Foundations.

[1]. Noll, D.C., Nishimura, D.G., Macovski, A., *IEEE Trans Med Imaging* 10, 154-163, 1991.

[2]. Lee, A.T., Glover, G.H., *Magn Reson Med* 33, 745-754, 1995.

[3]. Xiong, J., Gao, J.H., Lancaster, J.L. et al., *Hum Brain Mapping* 3, 1-15, 1995.