핵자기 뇌기능 영상에서 Clustering 기법을 이용한 영상처리

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Image Processing Method Using a Clustering Technique in fMRI

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INTRODUCTION

The sensitivity of a gradient echo MRI signal to dephasing of spins in local magnetic field gradients provides a means to detect differences in tissue oxygenation (1-3). The susceptibility-induced signal change in fMRI (functional Magnetic Resonance Imaging) has been processed by various processing techniques, such as a simple subtraction technique, a correlation technique, student t tests, and least-square technique (4-7). Generally, the brain function maps created by subtraction of magnitude images obtained during a resting state from magnitude images of the same tissue obtained during activation (3). The advantage of the subtraction technique is its speed and simplicity. But this simple subtraction technique contains other physiological processes such as CSF flow, gross motion, and pulsatile brain motion and these physiological processes contribute to artifactual signal changes unrelated to true neuronal activity. So a number of different mathematical approaches to fMRI data analysis have been proposed and implemented such as correlation analysis, student t tests, least-square analysis, and principle-component analysis (4-7). Among the techniques the correlation technique is widely used in fMRI data processing. A new proposed CLT (clustering threshold) technique is a modified CCT (correlation coefficient threshold) technique and has many advantages compared with the CCT technique.

Using a new clustering threshold (CLT) technique which is a modified CCT technique, the real activated pixels can be clustered and the spurious pixels can be suppressed. A visual cortex activation paradigm is used to compare the postprocessing techniques of image subtraction and the CCT technique and to illustrate the effectiveness of the new CLT technique. All functional experiments are performed on a whole body KAIS 2.0T NMR system.

THEORY

For the time course analysis of the functional imaging, several methods have been developed (4-7). Among the methods, recently the CCT technique is widely used. The technique uses the correlation coefficient, cc, for each pixel and given by

$$cc = \frac{\sum_{i=1}^{N}(t_i - m_t)(r_i - m_r)}{\left[\sum_{i=1}^{N}(t_i - m_t)^2\right]^{1/2}\left[\sum_{i=1}^{N}(r_i - m_r)^2\right]^{1/2}} \qquad [1]$$

where t_i ($i = 1,2, \cdots, N$) is the time-course function data in a given pixel, r_i is the reference waveform, and m_t and m_r are average values of t_i and r_i, and given by

$$m_t = \frac{1}{N}\sum_{i=1}^{N} t_i$$

$$m_r = \frac{1}{N}\sum_{i=1}^{N} r_i\,. \qquad [2]$$

The cc value is a measure of the correspondence of the shapes of the reference waveform and the functional time-course waveform. The reference waveform may be experimental time-course function data in some particular pixel or an average of several experimental data or definite artificial wave form such as the box-car waveform. The value of cc always varies -1 to +1. A threshold value TH was set between 0 and +1 and data in each pixel were selected based on

$$cc \geq TH. \qquad [3]$$

This thresholding technique rejects noise but also suppresses spurious correlation in pixels with large signal changes by pulsatile blood and cerebral spinal fluid (CSF) flow (8) and takes advantage of the time course information by computing the correlation coefficients between the time response of a pixel with a reference signal. Two primary disadvantages of this method are that a false positive pixel may be detected as a real activated real pixel and that the selection of the reference signal requires some form of a priori knowledge. The larger the threshold value TH, the more closely the shapes resemble the functional waveform and reference waveform. Although the shapes closely resemble but true positive pixels that have a low cc value may be rejected at large TH. Otherwise the smaller the TH value, the less resemble the functional waveform and reference waveform, but having low cc value true positive pixels are alive. Therefore, proper decision of the TH value is necessary.

Clustering Threshold (CLT) Technique

Although the functional data obtained by the above technique provides a high degree of contrast-to-noise with the proper selection of the threshold value TH, this method provides discrete pixel data and often false positive pixel data due to signal noise. An alternative technique, which relies on the assumption that areas of true neural activity will tend to stimulate signal changes over contiguous pixels, is presented (9).

The CLT technique is explained by the two steps. A shot noise pixel is rejected at the first step and a clustering operation is performed at the second step. First, the CLT technique utilizes an n×n matrix box which scans the whole N×N image matrix as shown as in Fig. 1. If we have obtained correlation coefficient pixels map above the proper TH value using the CCT technique as shown as in Fig. 1, which is discrete and includes splash noise data, then we now can reject the spurious pixels and extract the real neural activity pixels using a n×n matrix box. For example, when a 3×3 matrix box scans the whole N×N image matrix, a center pixel that surrounded by another threshold above pixel in the 3×3 matrix box is considered as a real neural activity pixel. On the other hand a center pixel that did not surrounded by another threshold above pixel in the 3×3 matrix box is a considered as a shot noise and rejected. Second, a clustering operation is performed as shown in Fig. 2 and Fig. 3. The n×n matrix box that used at the first step also scans the whole N×N image matrix. The separation rule whether a unactivated center pixel in the scan box is considered as a real activated pixel or not is described by the two cases in Fig. 2. If a unactivated pixel were surrounded by real activated pixels such as in Fig. 2(a) and (b), the center pixel is corrected as a activated pixel.

Real data processing is not processed separately by the above two steps but simultaneously processed at the same time. This technique relies on the assumption that interesting areas of neural activity will tend to be larger than individual pixel dimensions in fMRI, and, as such, will tend to over contiguous groups of pixels. This method takes advantage that a spurious noise pixel is rejected and a hidden real activated pixel is alive.

EXPERIMENTS

Experiment was performed on a 2.0 Tesla whole body MRI system using a standard head coil. A Conventional Gradient Echo (CGE) pulse sequence having first-order gradient moment nulling for reduction of inflow effect was used. Visual activation was performed by photic stimulation using a home-made 8Hz LED checker board. For the functional imaging, a single oblique slice of 10mm thick which was located near the calcarine fissure carefully selected with an imaging time of 7sec. The FOV was 24cm, TR/TE=58/30msec, and α=50°. 15 image sets were acquired from the same slice at equally spaced intervals of time in series. A set of baseline images was obtained in image number from 1 to 5, and a consecutive set of stimulation images was obtained in image number from 6 to 10 with continuous visual activation and again image numbers from 11 to 15 were obtained at rest state.

The fMRI data processing was performed using the two steps. First, the CCT technique was used for functional mapping. Second, the CLT technique was used for same functional mapping.

RESULTS AND DISCUSSION

Figure 4 shows functional mapped images that superimposed with red color pixels on the base image when data processed with the CCT and CLT techniques. The left column ((a), (b), (c)) images were processed by CCT technique by varying threshold value (TH=0.5, 0.6, 0.7). Many individual noise pixels were randomly distributed at the low TH value shown as in Fig. 4(a). The larger the TH, the smaller pixels that more correlative with reference waveform were selected. Although the noise pixels were suppressed with a larger TH, the real activation pixels that have low cc value were also rejected. The right column ((d), (e), (f)) images were processed by the CLT technique with a 3×3 matrix box. The threshold value is also varied for comparison to the CCT technique. Many individual noise pixels were rejected even at the low TH value and at the same time real activated pixels which have relative low cc value remain in the image by the cluster threshold technique.

The CLT technique has variable parameters such as n×n matrix box, threshold value, and other factor such as clustering strategy. Although only a 3×3 matrix box was used in our data processing but variable n×n matrix boxes will be used for various purposes. This technique has various advantages compare to the CCT technique. Namely the real neuronal activated pixels can be clustered and the false spurious pixels can be suppressed by the new CLT technique. In conclusion, a post processing in fMRI proposed the CLT technique has advantages among other existing techniques. Especially it is proved to be robust for noisy environment. Experimental data processed by the CLT technique show that activated region is more correlated with neural area such as cortex area.

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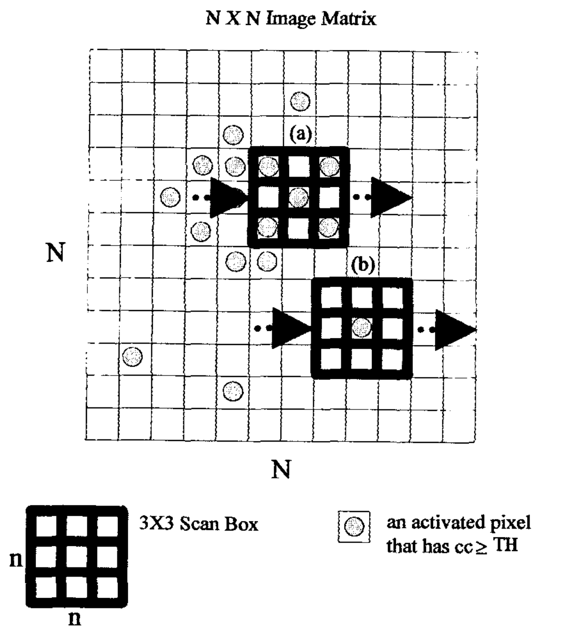

Fig. 1. A 3X3 scan matrix box scans the NXN whole image matrix to reject the noise pixels. (a) the center pixel in the scan box is a consider as a real activated pixel. (b) the center pixel in the scan box is a considered as a shot noise and rejected.

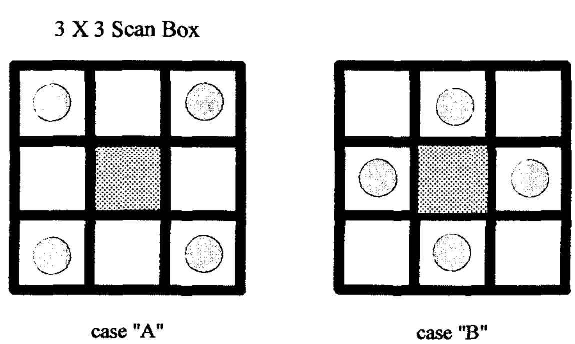

Fig. 2. Two cases that a unactivated center pixel in the scan box is considered as a real activated pixel.

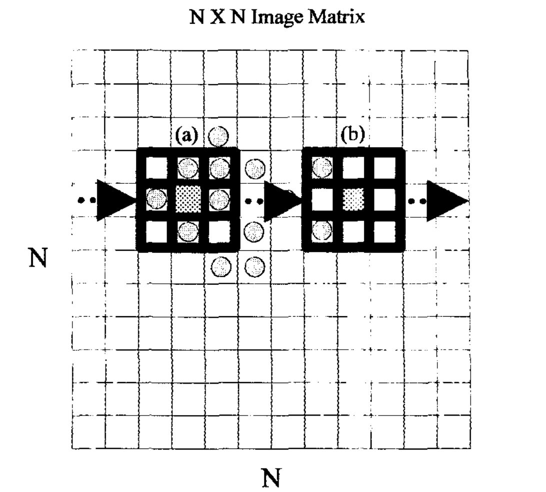

Fig. 3. A clustering operation. (a) a unactivated center pixel in the scan box is considered as a activated pixel. This is a case "B" as shown in Fig. 2. (b) a unactivated center pixel in the scan box is considered as a unactivated pixel.

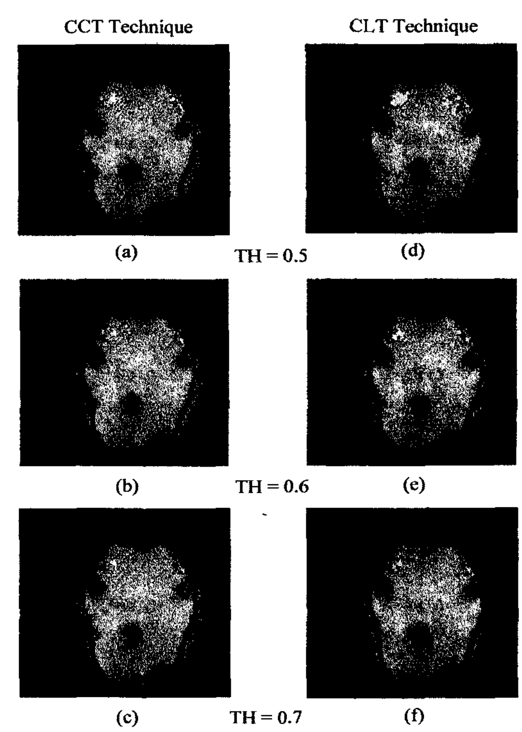

Fig. 4. The functional mapped images that superimposed with red color pixels on the base image when data processed by the CCT and CLT techniques. The left column ((a),(b),(c)) images were processed using the CCT technique by varying threshod value (TH=0.5,0.6,0.7). The right column((d),(e),(f)) images were processed using the CLT technique by varying threshod value (TH=0.5,0.6,0.7).