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# 핵자기 뇌기능 영상에서 군집경계기법을 이용한 영상처리법

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=Abstract=

## The Clustering Threshold Image Processing Technique in fMRI

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The correlation technique has been widely used in fMRI data processing. The proposed CLT (clustering threshold) technique is a modified CCT (correlation coefficient threshold) technique and has many advantages compared with the conventional CCT technique. The CLT technique is explained by the following two steps. First, once the correlation coefficient map above the proper TH value is obtained using the CCT technique which is discrete and includes splash noise data, then the spurious pixels are rejected and the real neural activity pixels extracted using an $n \times n$ matrix box. Second, a clustering operation is performed by the two correction rules. The real neuronal activated pixels can be clustered and the false spurious pixels can be suppressed by the proposed CLT technique. The proposed CLT technique used in the post processing in fMRI has advantages over other existing techniques. It is especially proved to be robust in noisy environment.

**Key words** : functional Magnetic Resonance Imaging, correlation technique, clustering technique

## INTRODUCTION

The sensitivity of a gradient echo MRI signal dephasing of spins in local magnetic field gradients provides a means to detect differences in tissue oxygenation[1~5]. The sensitivity-induced signal change may be processed by various processing techniques for analyzing the human brain functions[6~11]. In general, 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[3~5]. 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. These physiological processes may contribute to artifactual signal changes unrelated to true neuronal activity[6]. Previously a number of different mathematical approaches to fMRI data analysis have been proposed and implemented

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such as correlation analysis, student-t tests, least-square analysis, and principle-component analysis[6~11].

In this paper, two image processing techniques are described to obtain high contrast-to-noise brain functional images. The correlation coefficient threshold (CCT) technique that uses the shape of the time-course signal for the decision criterion is described[6]. Although the functional data obtained by the CCT technique provides a high degree of contrast-to-noise, this method provides discrete pixel data and often false positive pixel data due to signal noise. The new CLT technique is proposed to overcome the disadvantages in CCT technique. A visual cortex activation paradigm is used to compare the postprocessing techniques such as subtraction technique and the CCT technique, and to illustrate the effectiveness of the new CLT technique.

## THEORY

### A. Correlation Coefficient Threshold (CCT) Technique

For the time course analysis of the functional imaging, several methods have been developed[6~11]. Among the methods, the CCT technique has been widely used. The technique uses the correlation coefficient, cc, for each pixel and given by

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

where $t_i$ (i=1,2,⋯, 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 $r_i$, respectively, 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 value 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. Figure 1 displays two reference waveforms. A box-car waveform used in creation of the our CCT image is shown in Fig. 1 (a). A actual pixel reference waveform that responses of one pixel in the actual data set is shown in Fig. 1 (b). Because the temporal response of the MR signal to functional brain activity is an incompletely understood process, the use of ideal box-car waveform as the basis for correlation is necessarily to simplify. The value of cc varies from −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[12]. The technique also 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 resemble closely, the true positive pixels that have a low cc value may be rejected at large TH. Otherwise the smaller the TH value, the less it resemble the functional and reference waveform, but true positive pixels are alive in low cc value. Therefore, it is necessary to decide the TH value properly.

### B. Clustering Threshold (CLT) Technique

Although the functional data obtained by the CCT 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[11].

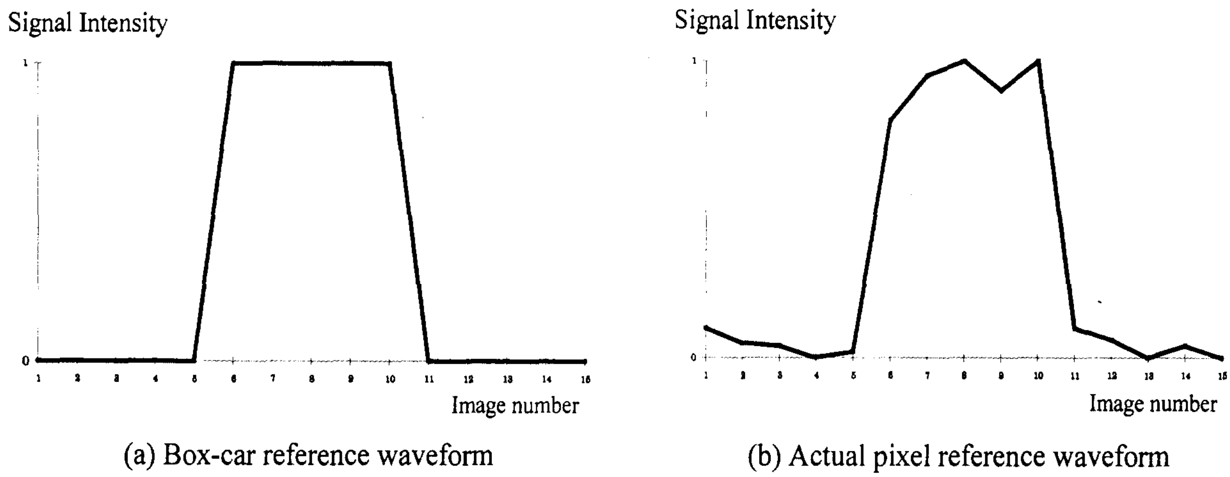



**Fig. 1.** Two reference waveforms. **(a)** Box-car reference waveform **(b)** Actual pixel reference waveform

The CLT technique is explained by the following 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 in Fig. 2. Once the correlation coefficient map above the proper TH value is obtained using the CCT technique as shown in Fig. 2, which is discrete and includes splash noise data, then the spurious pixels are rejected and the real neural activity pixels extracted using an n×n matrix box. For example, when a 3×3 matrix box scans the whole N×N image matrix, a center pixel surrounded by other threshold above pixels in the 3×3 matrix box is considered as a real neural activity pixel and alive. This is explained in Fig. 2(a). On the other hand, a center pixel not surrounded by any other threshold above pixel in the 3×3 matrix box is a considered as a shot noise and rejected. This is explained in Fig. 2(b). Therefore, the clustered pixels that are alive and discrete noise pixels are rejected by the first step. Second, a clustering operation is performed as shown in Fig. 3, Fig. 4 and Fig. 5. The n×n matrix box that is used in the first step also scans the whole N×N image matrix. A correction rule whether an unactivated center pixel in the scan box is

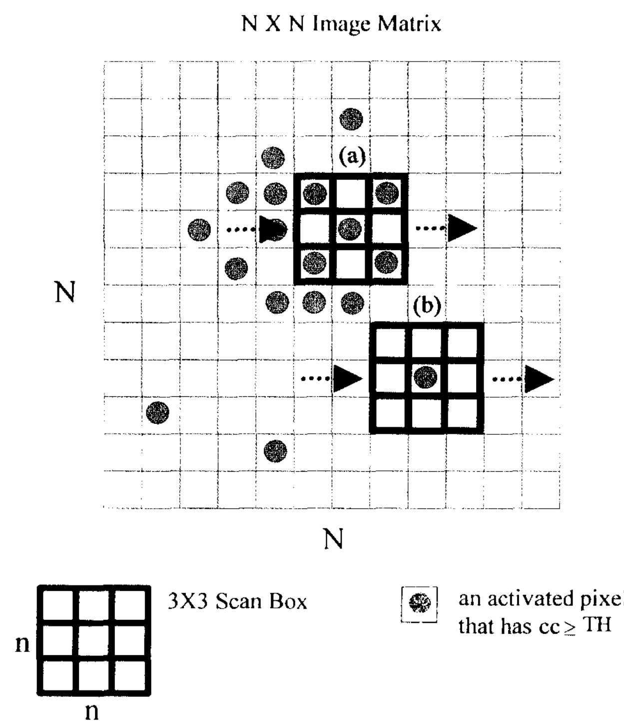



**Fig. 2.** A 3×3 scan matrix box scans the N×N whole image matrix to reject the noise pixels. **(a)** a yellow-colored center pixel in the scan box is considered as a real activated pixel and alive. **(b)** a yellow-colored center pixel in the scan box is considered as a shot noise and rejected.

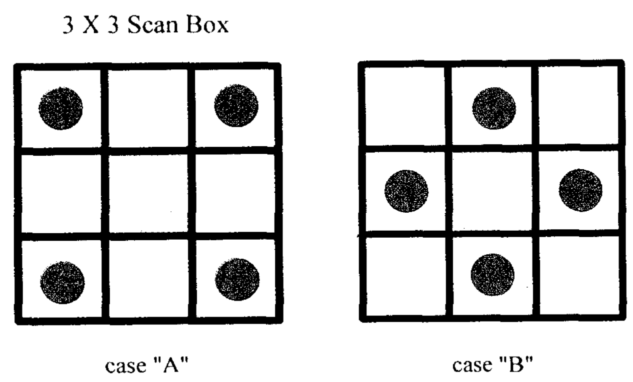



**Fig. 3.** Two correction rules. A yellow colored unactivated center pixel in the scan box is corrected as a real activated pixel and filled with red color circle.

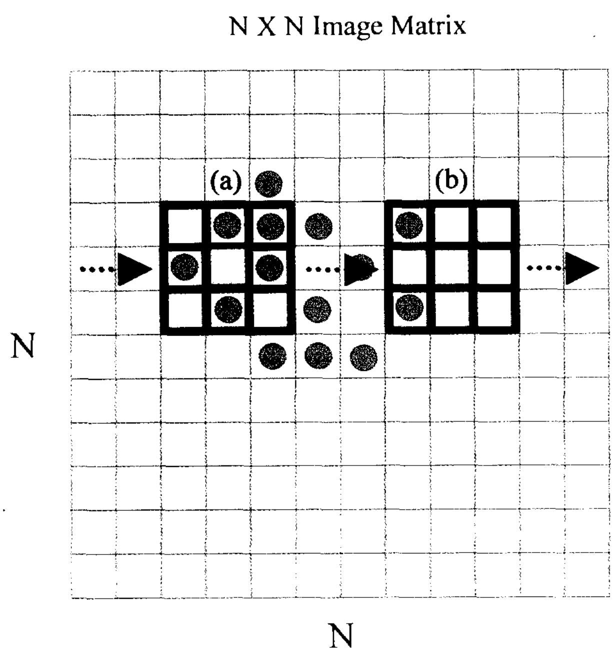



**Fig. 4.** A clustering operation. **(a)** A yellow colored unactivated center pixel in the scan box is correctedd as an activated pixel and filled with red circle. This is a case "B" as shown in Fig. 3. **(b)** A yellow colored unactivated center pixel in the scan box is not changed. This case do not satisfy either of the two correction rule.

considered as a real activated pixel or not is described by the two cases in Fig. 3. If an unactivated pixel was surrounded by real activated pixels such as shown in Fig. 3 (a) and (b), the unactivated center pixel is corrected as an activated pixel and is filled with red color circle. Any other unactivated pixels that are not satisfied by either of the above two correction rules remain unchanged. An example of the correction rule is presented in Fig. 4.

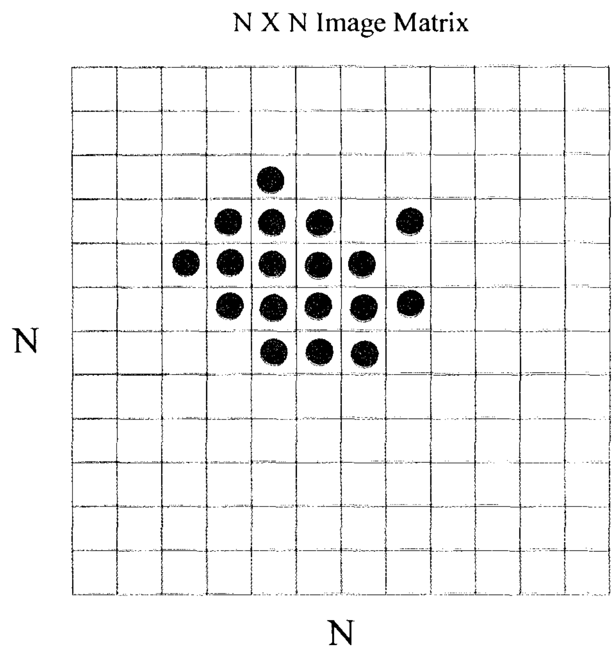
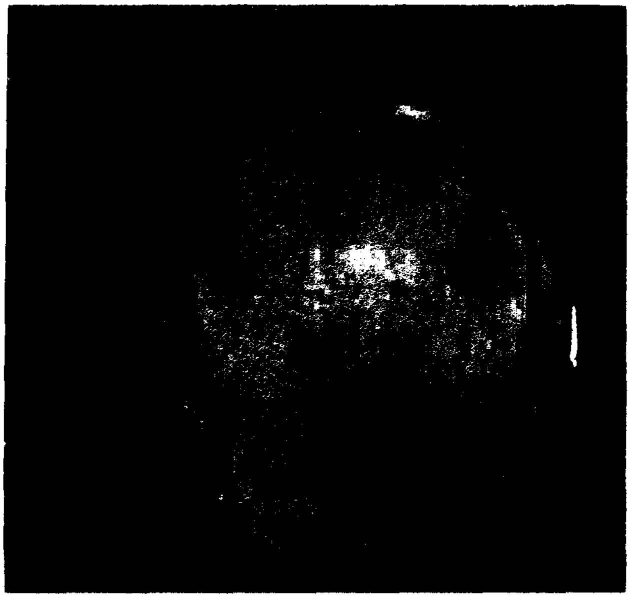



**Fig. 5.** After a clustering operation, unactivated pixels are filled with red color circles when the pixels satisfy either of the two correction rule.

Therefore, Fig. 2 is changed into Fig. 4 by the first step, and Fig. 4 changed into Fig. 5 by the second step. 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 cover contiguous groups of pixels.

## EXPERIMENTS

An 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 sel-



(a) Base Image

(b) Subtraction Image

**Fig. 6.** Simple subtraction technique. **(a)** The average image of 1 to 5 **(b)** The average image from 1 to 5 (average of base images) was subtracted from the average image of 6 to 10 (average of stimulation images). Two black arrows indicate areas of neural activity.

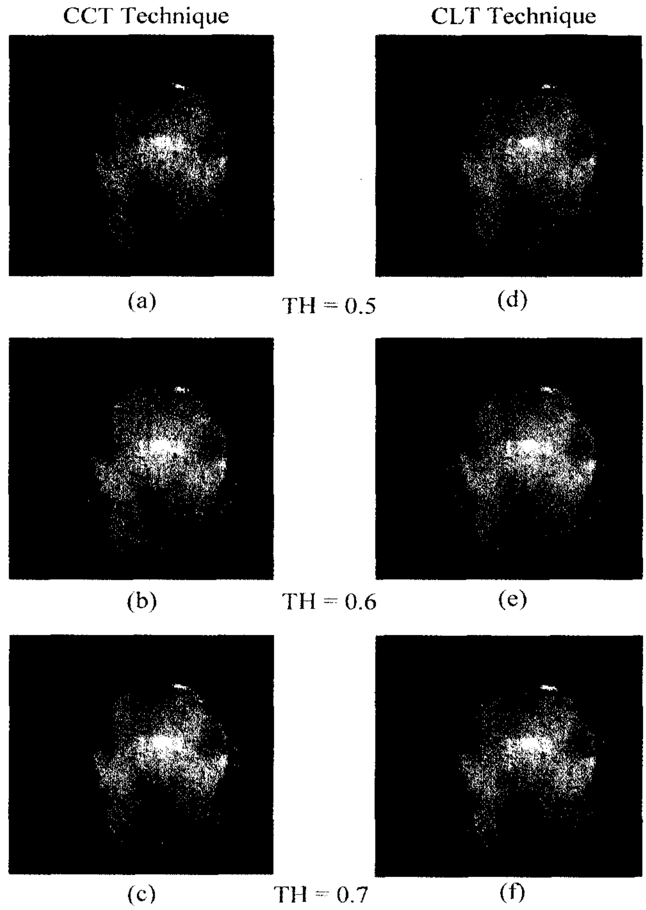



**Fig. 7.** The functional mapped images superimposed with red color pixels on the base image using the CCT and CLT techniques. The left column ((a),(b),(c)) images were processed using the CCT technique by varying threshod value (TH=0.5,0.6,0.7). The right column ((d),(e),(f)) images were processed using the CLT technique by varying threshod value (TH=0.5,0.6,0.7).

ected with an imaging time of 7sec. The FOV was 24cm, TR/TE=58/30msec, and $\alpha=50^\circ$. 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 three techniques. First, the subtraction technique was performed. Next the CCT technique was used for functional mapping.

Finally, the CLT technique was used for same functional mapping.

## RESULTS AND DISCUSSION

The average of images from 1 to 5 (average of base images) was subtracted from the average of images from 6 to 10 (average of stimulation images) and displayed in Fig. 6 (b). Although two black arrows indicate obvious areas of neural activity, the artifactual signal enhancement is sparsely presented in the image. Figure 7 shows functional mapped images 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 in Fig. 7 (a). The larger the TH, the pixels that more correlated with reference waveform were selected. Although the noise pixels were suppressed with a larger TH, the real activation pixels of low cc value were rejected. The right column ((d),(e),(f)) images were processed using the CLT technique with a 3×3 matrix box. The threshold values were also varied for comparison to the CCT technique. Many individual noise pixels were rejected even at the low TH value. At the same time real activated pixels which have relatively low cc value were remained in the image by the cluster threshold technique.

The CLT technique has variable parameters such as an 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, a variable n×n matrix boxes may be used for other purposes. This technique has some 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, the proposed CLT technique used in the post processing in fMRI has advantages over other existing techniques. It is especially proved to be robust in noisy environment.

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**=국문초록=**

핵자기 공명 뇌기능 영상에서 상관관계를 이용한 데이터 해석기법이 많이 사용되고 있다. 이 논문에서 새롭게 제안된 CLT 기법은 상관관계(CCT)를 이용한 기법을 변화시켜서, 이 CCT 기법의 단점을 보완하고자 하였다. CLT 기법은 다음의 두 단계로 이루어진다. 첫째, 잡음을 포함한 CCT 기법의 상관계수결과로 부터 잡음은 제거하고 실제 자극반응 픽셀들은 추출한다. 둘째, 이산적인 분포를 가지는 반응 픽셀들을 두 가지의 선별법으로 군집을 이루도록 한다. 이 CLT 기법을 이용해서 실제 자극에 반응하는 픽셀들은 서로 모이게 하였고, 잡음에 기인한 오류의 픽셀들은 제거 되어질 수 있었다. 본 논문에서 제안된 CLT 기법은 기존의 다른 기법에 비해 여러 잇점이 있고, 특히 잡음에 강한 특성이 있다.