Automatic Extraction of Tissue Form in Brain Image

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(Received September 15, 2001; Accepted October 22, 2001)

Keywords: Brain MR Image, Automatic Extraction, Clumsy Painter Method, Brain Parenchyma

Abstract. For simulation of surgical operations, extraction of selected regions from MR images requires a high level of skill and experience from the physicians. We have developed a unique automatic extraction algorithm for extracting three dimensional brain parenchyma from MR head images. This method has advantages compared with the morphological filtering (SERRA, 1982, 1986; HARALIK *et al*., 1987) and the region growing method. As first step, this method was applied to binarized images, but there were some problems in that the results of extraction varied much with the value of the threshold level (SATO *et al*., 1997). As second step, the method was applied to gray scale image, but misextraction was caused because density in the contour of object change, locally. Finally, images having information corresponding to the property of human tissues, respectly, are introduced. The characteristics of this method is that an extracted form is not an exterior of the object, but the form of a set of picture element having a physical property. We could improve extraction accuracy. As a results, the over extracted ratio was improved by 36%, and the under extracted ratio was improved by 20%.

1. Introduction

The algorithm is named "three dimensional gray scale clumsy painter method." In this method, a template having the shape of a pseudo-circle, a so called Clumsy painter (CP), moves along the contour of the selected region, and the region surrounded by the contour is extracted (Fig. 1)

2. Method

The algorithm of the method is divided into two processes. The first and the second ones called the edge-searching process and the edge-following process, respectly. The purpose of the first process is to set an appropriate initial condition, where the initial point of the template is placed manually so that the template is included in the interesting region. A template that the shape is simular to circle (Fig. 2), moves along the contour of region of interest, after the image of the cerebral parenchyma was transferred to binary image,

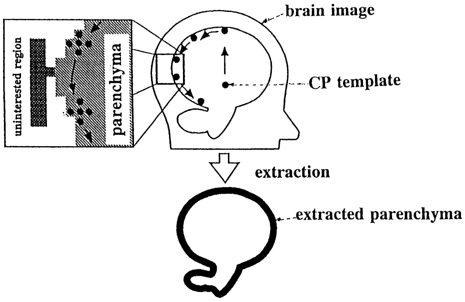

Fig. 1. Schematic diagram of brain parenchyma extraction process. The brain image is presented in binary pattern, and the CP template is placed on the optional point in area of interest. After that, the CP template is moving by the transfer rule, and the contour of brain parenchyma is searched, and a locus of the template is produced. By closing of the locus, the contour is tracked, and the region surrounded by contour is extracted.

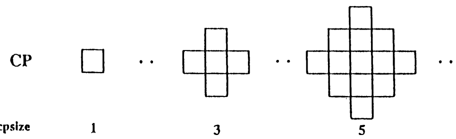

Fig. 2. Digital shape of CP template in two dimensional CP method. CP template is similar to a circle, and the size of template is choose, optionally.

after that the region of interest is extracted. But, by asking an adequate threshold for every binary image, the pursuit of good results was difficult.

To solve this problem, we expanded the moving condition of CP template so as to be able to apply to gray scale image. The moving condition of template was not fixed in the whole image, but was given as a map of vector in CP template (Fig. 3). The requirement for the template moving condition is shown in the following equation.

$$t_l(p) \leqq g(p + w_{i-1} + d_i) \leqq t_u(p) \tag{1}$$

where, p is an element of CP, w_{i-1} is a CP position after (i–1)th moving, d_i is a vector of i-th movement, $g(a)$ is an image density of position a, $t_l(p)$ is a map of the vector giving lower limit to p, and $t_u(p)$ is a map of the vector giving upper limit to p.

A shape of these map in this method is decided for whole area of region of interest (ROI), therefore, misextraction is caused in case of which the density in the contour of brain change, locally. To solve the problem, it is useful to change shape of the map according to change of the image density, locally.

Finally, a method is proposed, T_2 weighted image and proton density image are used to bring the information corresponding to the property of tissue, respectively. Using these

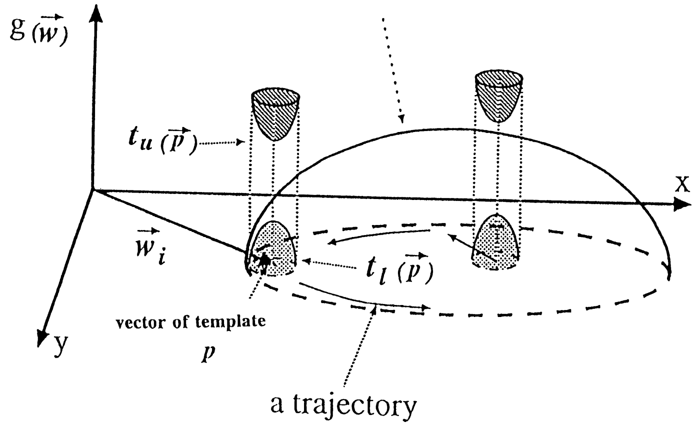

Fig. 3. Schematic representation of a trace of template in the edge of parenchyma. The threshold is given as a map of the vector of CP template in order to apply the proposed technique for gray scale image.

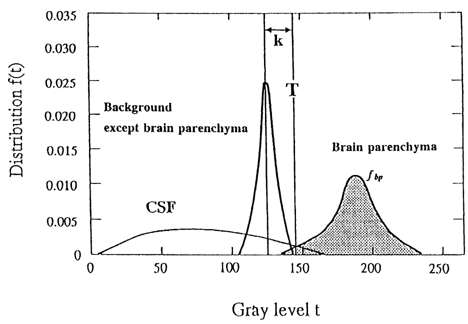

Fig. 4. Image density histogram of cerebral spinal fluid, brain parenchyma and background. The density histogram of the difference image at $t = 127$ corresponds to the background except for brain parenchyma, and density histogram of brain parenchyma shows normal distribution.

information in image density, several tissues are identified, and the boundaries between every tissue become clear.

It is well known that, on the condition of "proton density weighted gray level = T_2 weighted gray level", brain parenchyma and CSF can be separated, according to a literature about tissue classification (DAWANT *et al.*, 1993). It was confirmed that brain parenchyma and CSF are able to classify from the value of difference between proton density weighted gray level and T_2 weighted gray level.

$$g_{T2}(p + w_{i-1} + d_i) \leqq g_{PD}(p + w_i + d_i) + K$$

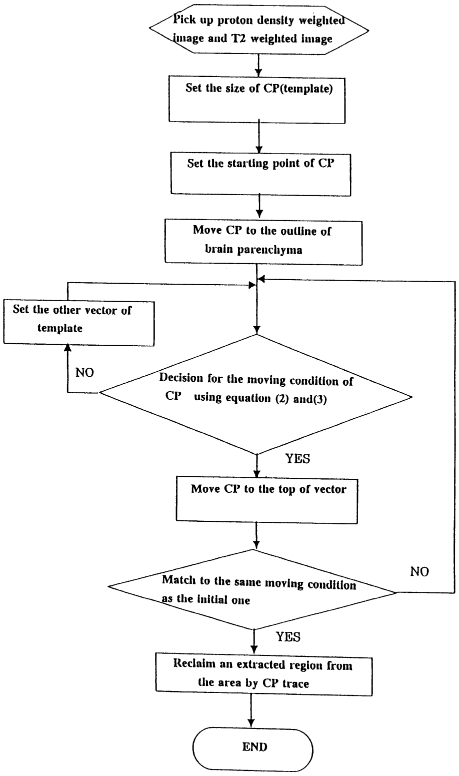

Fig. 5. Flow chart of automatic extraction of interested region.

where g_{T1} is density of T_1 weighted image on the position $p + w_{i-1} + d$, g_{PD} is density of proton density image on the position $p + w_i + d_i$, K is a parameter that decides the boundary separating brain and CSF.

Decision process which decides the adequate K is introduced from the histogram of the difference image between T_2 weighted image and proton density image. The histogram of difference image density is shown in Fig. 4.

From Fig. 4, threshold (t) in the difference image is asked.

$$T = \mu - 3 \cdot \sigma. \qquad (2)$$

f_{bp}: distribution of brain parenchyma, μ: average of f_{bp}, σ: standard deviation.

From t, K is asked.

$$K = t - 127. \qquad (3)$$

The above algorithm is shown in the flow chart (Fig. 5).

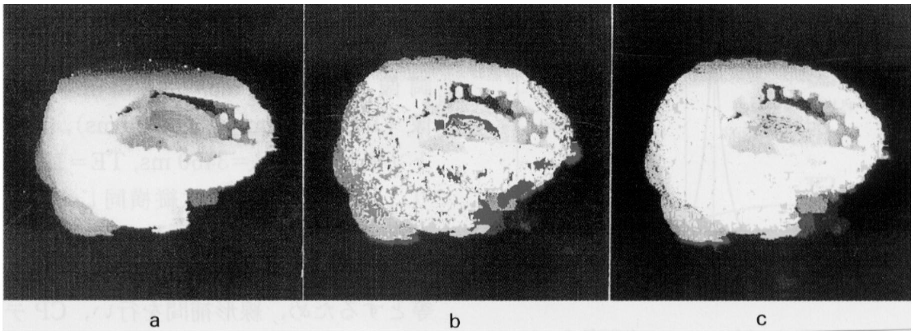

Fig. 6. The results of manual extraction (a), traditional extraction (b), and proposed extraction (c). It is the photograph in which the extracting results of the brain region were shown by three dimensional display. As a reference for extraction evaluation, a result by the manual extraction is shown in (a). The result by the traditional extraction technique was shown in (b), and the result by the proposed technique was shown in (c). In (a), white area is shown as the correct brain region. In comparison with white area of (b) and (c), the proposed method could be recognized as the superior advanced one.

3. Results and Discussion

To evaluate the accuracy of extraction, over extraction ratio E_o (%), and under extraction ratio E_u (%) is defined in comparison with the region of manual extraction, as follows:

$$E_o = \rho(U \cap S)/\ \rho(U) \times 100, \tag{4}$$

$$E_u = \rho(I \cap S)/\rho(I) \times 100. \tag{5}$$

Where, I is a set of picture element that construct region of interest, S is a set of picture element in area extracted, U is a set of picture element that construct unconcern region, $\rho(X)$ is number of picture element including in set X.

As a results, extraction accuracy was improved to $E_o = 1.16$, $E_u = 1.95$ from $E_o = 1.79$, $E_u = 2.44$. Usually, three dimensional images are shown in order to visualize the improvement of extraction accuracy.

The part of over extraction region is use to be displayed in the magenta colour, and the part of under extraction is used to be displayed in yellow. But, as Fig. 6 is displayed in black and white image, white area is displayed as the correct extracted region.

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