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A Detection Method for Carotid Artery Calcification in Dental Panoramic Radiographs

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Abstract- **This paper proposes a detection method for carotid artery calcification in dental panoramic radiographs. The existence of the carotid artery calcification as an index for arteriosclerosis attracts a great deal of attention. The carotid artery calcification has brighter intensity compared to the neighborhood region and its fact is utilized in the proposed method. To compensate the bad contrast of the dental panoramic radiographs, we also employ the fuzzy image contrast enhancement and algebraic image operator to the proposed method. From experimental results, the carotid artery calcification region can extract from several dental panoramic radiographs.**

I. INTRODUCTION

Recently, it has been discussed whether the presence of the carotid artery calcification in dental panoramic radiographs can predict the risk of vascular diseases among the aged [1]. In this discussion, it is pointed out that it does not always give rise to the vascular diseases, however may be possible.

The blood vessel disease like as a stroke stands first in the cause of Japanese death and the main part of sudden death in Japan. A cause of sudden pathogenesis is that the calcification has no subjective symptom. Therefore a patient is hard to know it and loses the chance of check up. It is important to find early the symptom of the calcification for preventing the sudden pathogenesis.

In dental treatment, dental panoramic radiographs are often taken for the checkup. In this image, a carotid artery next to the oral cavity is often included and the calcification in it is also found. Therefore by using an image for dental treatment, the dentist can find the presence of the calcification, explain the possibility of the blood vessel diseases to his patient and recommend consulting a physician. Then the sudden pathogenesis of the blood vessel diseases can be prevented.

In this paper, we propose an algorithm for the detection of the carotid artery calcification in dental panoramic radiographs. We note that the intensity of the calcification region is slightly higher than that of its neighbor. Then for extraction of the calcification region, the regions whose intensity is brighter than the mean one in the processing region are extracted and too small areas are also omitted. The contrast of the dental panoramic is bad and fuzzy image contrast enhancement [2] is adapted to the improvement of it. Experimental result shows the effectiveness of the proposed technique.

II. FUZZY IMAGE CONTRAST ENHANCEMENT

For the contrast enhancement of the carotid artery calcification region, we apply the fuzzy image contrast enhancement which is shown in Fig. 1. This method consists of three steps, transformation from intensity values in image to membership values on fuzzy domain, image enhancement in fuzzy region and inverse transform from membership values to intensity values.

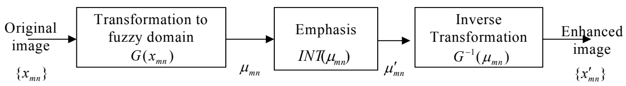

Fig. 1 Fuzzy image contrast enhancement.

1) Transformation to the fuzzy domain

The mapping function $G(x_{mn})$ is used for transformation from the intensity value $\{x_{mn}\}$ in an image to the membership value $\{\mu_{mn}\}$ on the fuzzy domain. Some mapping functions are proposed for this purpose. In this paper, we apply the following sine wave function proposed by Gupta et al. [3] as the mapping function:

$$\mu_{mn} = \begin{cases} \frac{1}{2}\left[1 + \left|\sin\frac{\pi(x - x_{cm-1})}{x_{cm} - x_{cm-1}}\right|^g\right], x_{cm-1} \le x \le x_{cms} \\ \\ \frac{1}{2}\left[1 - \left|\sin\frac{\pi(x - x_{cm-1})}{x_{cm} - x_{cm-1}}\right|^g\right], x_{cms} \le x \le x_{cm} \end{cases} \quad (1)$$

To apply this, the detection of valley points x_{cm} in the histogram of the image is required.

2) Enhancement

By applying enhancement operation to the membership value $\{\mu_{mn}\}$ on the fuzzy domain, emphasized one $\{\mu'_{mn}\}$ can be obtained. The following enhancement operator proposed by De et al. [4] is used in this paper:

$$\mu'_{mn} = \begin{cases} \frac{1}{2}[1 - \{\frac{\sin\theta_1(1-2\mu_{mn})}{\sin\theta_1}\}^{p1}], 0 \le \mu_{mn} \le 0.5 \\ \\ \frac{1}{2}[1 + \{\frac{\sin\{\theta_2(1-2\mu_{mn})}{\sin\theta_2}\}^{p2}], \ 0.5 \le \mu_{mn} \le 1.0 \end{cases} \quad (2)$$

where $0 \le \theta_i \le \pi/2$, $0 \le p_i \le 1.0$, $i = 1,2$.

3) Inverse transformation to the image

The inverse mapping function $G^{-1}(\mu'_{mn})$ is applied to the transformation from the emphasized membership value

$\{\mu'_{mn}\}$ to the intensity value $\{x'_{mn}\}$. This intensity value is emphasized compared to the original intensity. The inverse function of Eq. (1) is used in this paper.

In the transformation to the fuzzy domain, the valley points x_{cm} in the histogram should be detected for the setting of the threshold levels. The shape of image histogram become complex by several reasons like as noise, quantization and others. Therefore some suitable smoothing should be required for the effective detection of valley points. In this case, Savitzky-Golay filter [5] which is used for the smoothing of noisy wide band signal is adopted.

After the smoothing of the histogram, the detection of the valley points carries out by the following procedure [6]. The number of the valley points can be automatically decided.

1) Preliminary analysis of the histogram

According to the difference between a point and its neighbor point in the histogram, their points are classified into 3 classes and the histogram is converted to the sequence presented by these. In this sequence, the value 1 means the difference is positive, -1 negative and 0 no difference.

2) Shape analysis

The valley point is considered as the point at which the value in the sequence changes from -1 to 1. The reduced sequence which is represented by only 1 or -1 is given through the deletion of all 0s in the sequence. In this case, some conversion rules for the sequence shown in Fig. 2 are used. In this figure, D (down) means -1, U (up) 1 and F (flat) 0, and the solid line indicates the shape of histogram.

3) The detection of the valley points

In the reduced sequence, transition points from -1 to 1 are regarded as the valley points.

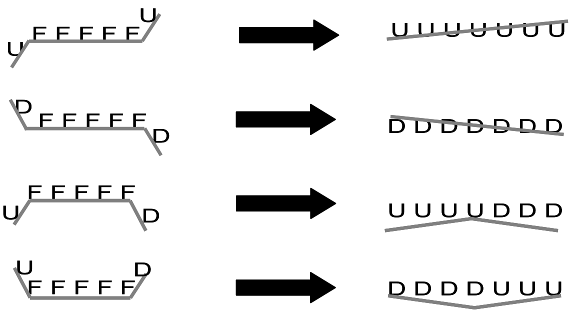

Figure 2 Conversion rules.

III. EDGE EXTRACTION IN FUZZY DOMAIN

First of all, algebraic representation of an image which lies at the foundation of the algebraic image operator [7] is described. Let a grayscale or binary image *A* represent the following expression:

$$A = \{(x, y) \in Z \times Z \mid \mu_A(x, y) \in [0,1]\}, \qquad (3)$$

where $\mu_A(x, y)$ indicates the membership value at (x, y) which lies between 0 and 1 and its value is proportional to the intensity level. *Z* also indicates the set of integer. By this expression, *A* is considered to be a fuzzy set which consists of (x, y) elements of a fuzzy image.

The addition of grayscale images A and B is defined by

$$\begin{aligned} &A + B \\ &= \{(x, y) \in A \cup B \mid \\ &\mu_{A+B}(x, y) = \min[\max\{\mu_A(x, y), \mu_B(x, y)\}, \\ &\quad \max(1-\mu_A(x, y), 1-\mu_B(x, y))]\} \end{aligned} \qquad (4)$$

where $\cup$ means the union operator. The multiplication is also defined by

$$\begin{aligned} &A * B \\ &= \{ \sum_{\substack{(X_1,Y_1)\in A \\ (X_2,Y_2)\in B}} (x_1 + x_2, y_1 + y_2) \mid \\ &\mu_{A*B}(x_1 + x_2, y_1 + y_2) = \min[\mu_A(x_1, y_1), \mu_B(x_2, y_2)]\} \end{aligned} \qquad (5)$$

where $\sum$ means the addition defined by (4).

By (5), a gray scale image can be represented by polynomial expression. Let an image which consists of only one pixel and an intensity level which is presented by a membership value be $X = [1,0]$ and $\mu_x(1,0) = a$, respectively. From (5) the following relations are obtained:

$$X * X = X^2 = [1+1, 0+0] = [2,0],$$

and

$$\mu_{x^2}[2,0] = \min[\mu_x(1,0), \mu_x(1,0)] = \min[a, a] = a.$$

Therefore $X^m = [m,0]$ indicates a pixel on the x-axis with the intensity level a. Similarly a pixel on the Y-axis is represented by $Y^n = [0, n]$ and its intensity level $\mu_{y^n}(0, n) = [0, n] = b$, respectively. Generally the polynomial expression of image *A* can be represented by

$$A = \sum_{m,n\in A} \mu_{mn} X^m Y^n$$

where *m* and *n* are any integer numbers, and μ_{mn} means the membership value of the intensity level at (m, n) pixel.

For the polynomial expressed image, a difference operator is defined as

$$D = (1+X)(1+Y) + (1+XY), \qquad (7)$$

and its application to f image *A* is obtained as.

IV. PROPOSED METHOD

In this section, we apply the fuzzy image contrast enhancement to the detection of carotid artery calcification region in dental panoramic radiographs. The example of the image is shown in Fig. 3 and the target regions to be processed are indicated by white borders. Either region is used for the extraction of the carotid artery calcification region. In the following, extracting algorithm is described.

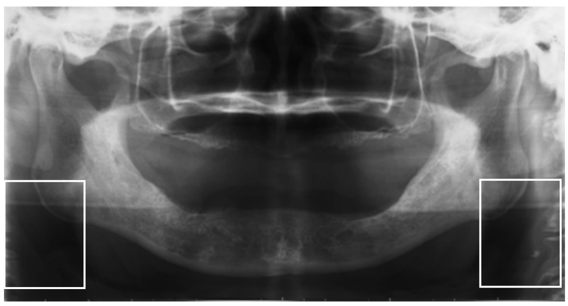

Fig. 3 Example of a dental panoramic radiograph.

i) Transformation from an original image to the image on fuzzy domain

The original image is transformed to the membership value image on fuzzy domain by using the multi-mapping function [3] based on Gupta's sine wave function.

ii) Image enhancement on fuzzy domain

The enhancement operator proposed by De et al. [4] is used in this step, since its characteristic is easily modified and the operation can be completed once. In this case, the parameters are selected as $P_1 = P_2 = 0.001$ and $\theta_1 = \theta_2 = \pi/2$. By these parameters, the membership values which are less than 0.5 are close to 0 and otherwise 1.0 for hard enhancement.

iii) Edge extraction in fuzzy domain

The algebraic image operator which is expressed by (7) is applied to the enhanced image for the edge extraction.

iv) Extraction of edges which enclose the object region

We assume that the carotid artery passes through the area between the outside of the spine and the outline of the throat. Naturally, the carotid artery calcification region exists in the same area. Next the longest edge is assumed as the outline of the spine, since the edges of the spine which is the longest bone in this region consist of many complex lines and curves. The second longest edge on the opposite side of the spine centering the object region is regarded as the outline of the throat, because this line has long but smoother curve compared to the outline of the spine. As a result, the object region can be extracted by the detection of the longest and second longest edges. Therefore, after the detection of the first and second longest edges by the labeling of the edge image, the reduced edge image which has only these edges is obtained. The region between these edges is considered as the object region.

v) Restoration of the intensities of the object region

On the reduced edge image, the pixels on the edges have 1 and otherwise 0. Then the bits of the reduced edge image are reversed and the bits of the regions which have the first and second largest areas are turned to 0. As a result, only the bits of the region between the first and second longest edges have 1. This mask image is multiplied by the original image. Then the image of the target region can be extracted.

vi) Edge extraction in the target region

The procedures from i) to iii) are applied to the image of the target region and the edge image of the target region is obtained.

vii) Edge extraction in the candidate region of the carotid artery calcification

The difference image between the edge images obtained from the procedure iv) and vi) is calculated and the edges in the candidate region of the carotid artery calcification are extracted.

viii) Restoration of the intensities of the candidate region of the carotid artery calcification

The intensities of the candidate region of the carotid artery calcification are restored by using the technique shown in the procedure v).

ix) Detection of the carotid artery calcification region

The carotid artery calcification region has brighter intensities than its neighbor region. Therefore the mean intensity is calculated from the candidate region and the regions which have darker intensities than the mean one are removed. Moreover the small reminded regions less than 200 pixels are also removed. This parameter is adopted by preliminary experiments.

V. Experimental results

To show the effectiveness of the proposed method, some experimental results are shown. Figures 4 and 5 show a part of the dental panoramic radiographs which have a calcification region in the carotid artery. In these figures, the areas enclosed by the white circle are the carotid artery calcification ones which are identified by a dentist. The obtained results are shown in Figs. 6 and 7. In these cases, we can detect the calcification region successfully. Especially, in Fig. 6, only the calcification region is detected. Figure 7 includes the miss detection region.

Figure 8 is also the dental panoramic radiograph which includes the calcification region and Fig. 9 shows its result, however this example shows the case where we cannot find the calcification region. In this case, we missed the detection of the candidate region of the carotid artery calcification; especially the edge detection of the spine was failure.

We applied the proposed technique to twenty dental panoramic photographs which are ten images include the carotid artery calcification and 10 do not include it. We can detect the carotid artery calcification for five images, however last five images cannot find it. For the case of healthy peoples, only two images can be judged correctly. To improve the accuracy of the detection is left for the future work.

VI. Conclusion

This paper has proposed a new detection method of the carotid artery calcification which is found in dental panoramic photographs. To detect it from low intensity image, the fuzzy image contrast enhancement and algebraic image operator are applied. From experimental results, we successfully detect the calcification region from 5 images among 10 images with it. However the improvement of the detection ratio and its accuracy is left for the future work.

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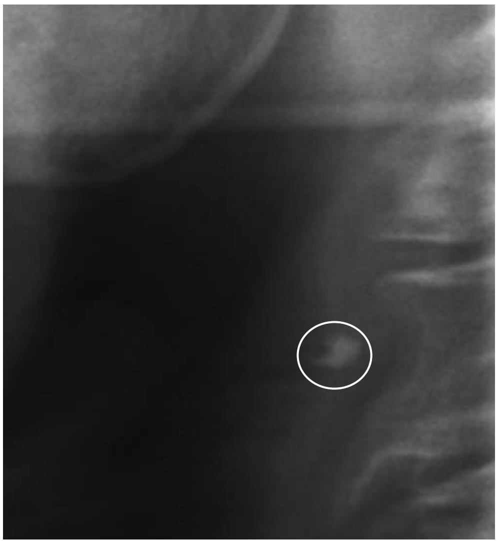

Fig. 4 Example 1.

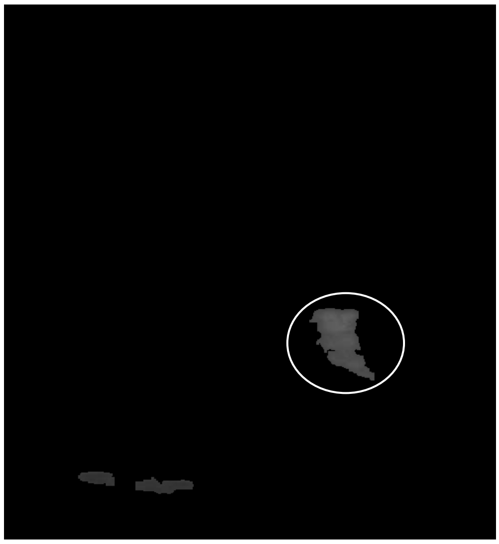

Fig. 7 Processing result of Fig. 5.

Fig. 5 Example 2.

Fig. 8 Example 3.

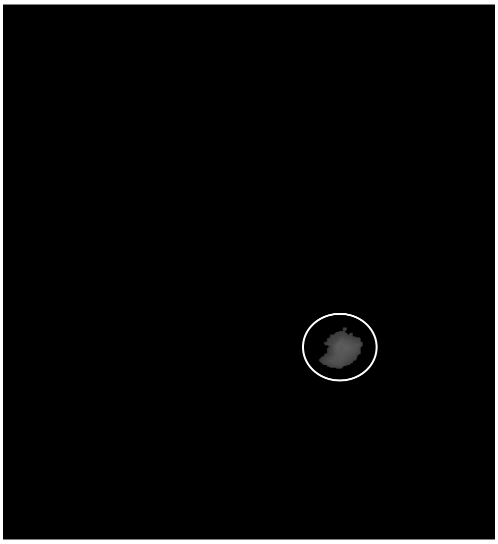

Fig. 6 Processing result of Fig. 4.

Fig. 9 Processing result of Fig. 8.