THE DETECTION OF TEETH ROOT TUBE USING ACTIVE CONTOUR MODEL

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Abstract: In this paper, the active contour model is modified and applied to trace the path of teeth root tube from the panogram. Firstly, the initial contour needs to be manually drawn near to the tube, and then the controlling and searching points are produced in sequence. Since the initial contour is an open curve in this study, the property of the smoothness can not be obtained in the starting and end points of the curve. Therefore, an additional energy term based on the best-orientation edge detector is introduced. Besides, the smoothness restriction terms for the curve and gray levels are both applied. The method of dynamic programming is employed to compute the energy in every controlling points and the position corresponding to the minimal energy are recorded. Finally, the similarity and the displacement are two parameters used for accuracy evaluation. From the experimental results, the proposed image analysis system can automatically locate the contour of the teeth root tube with the error of 7 pixels (about 3mm) in comparison with the manual measurement made by a experienced dentist. It is demonstrated to be useful in dentistry application.

Keyword: Active contour model, Dynamic programming, panogram, image analysis

Introduction

With the advance of material technology, the artificial tooth root which is made of Titanium alloy has been widely and successfully implanted in alveolus bone on the patient with missing tooth. In the process of implanting, dentists have to draw the path of teeth root tube manually in the tracing paper based on the parogram to check the size of root. Too long artificial root may probably damage the nerve and blood vessel in the tube and cause the face of the patient to be paralyzed.

Edge detector is a fundamental operator widely used to locate the edge of objects in image processing. However, for the medical image with low-contrast and noises, it is difficult to apply the edge detector. The traditional image processing methods only consider the variation of the intensity in the object and do not take the smoothness of edges into account. The active contour model is applied instead for its flexibility. It defines the energy for the curve of the edge. In 1987, Kass et al. [1] proposed the concept of active contour model. This method computes the property of curve and incorporates the traditional edge detection to find out the contour of the edges.

In Kass's algorithm, user firstly has to draw a closed contour near to the detected edge and then to give the definition of energy function for the contour. Afterwards, the contour is moved and changed toward the actual edges based on the energy. When the energy is at the minimum, the optimal contour can thus be obtained. In this study, the concept of Kass' algorithm and the method of dynamic programming proposed by Amini et al. [2][3] are applied to search the minimal energy contour. Due to the path of teeth tube is not a closed curve, the concept of best-orientation edge detector proposed by Yachida et al [4] is introduced in the energy function to compute the smoothness on the starting and end points of the contour. In addition, in order to increase the detection accuracy, the relation to quantify the smoothness of the intensity in the edge of the object is also added into the energy function.

Methods

The development environments including hardware and software for the proposed image analysis system are listed in Table 1. The input device is a desk-top scanner. A personal computer is used as the kernel of image analysis. The panograms are produced by the AUTO 2000 EXT (Asahi Roentgen Company). Fig. 1 shows the flow chart of the proposed image analysis procedure. The detailed descriptions of the procedure are summarized in the following.

(1) Image acquisition

The X-ray films of panogram are obtained from the Dental Department of the Chi-Mei medical center. Then, the film is scanned and digitized into digital image using scanner. Afterwards, the image is saved as "BMP" format for later processing.

(2) Image processing

In this step, the digital image is processed with the median filter for removing the noises. Then, histogram

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equalization is applied to enhance the selected region-of-interest.

(3) The initial contour selection

In the Kass's algorithm, the first step is to draw the initial contour good for edge detection. In this study, the initial contour is drawn manually by the dentist. Then, the controlling points are defined sequentially at an interval of 5 pixels on the contour. Five to ten searching points along the line perpendicular to the contour at the controlling point are located on each side to compute the energy for adjusting the contour.

(4) The weighting factors determination

According to the definition of energy function in the model: $E_{total} = \alpha E_{continuity} + \beta E_{smoothness} - \gamma E_{external}$, the determination of the weighting factor (α, β, γ) are very important since they dominate the property of the contour adjustment.

(5) The energy computation

The searching points that are acquired at every controlling point are labeled as a group. Since the smoothness term in the energy function for the ith group is computed from the v_{i-1}, v_i and v_{i+1}, the smoothness term for either the first or the last group may not be defined and found. Therefore, it is divided into two different forms according to the existence of the smoothness term.

A. The first or the last group of searching-points

For obtaining the position of the edge in both groups, the best-orientation edge detector is introduced into the energy function. Firstly, the difference value of the intensity between the two neighboring rectangular areas for every searching-point at the interval of 15° from -90°to 75°is computed. Then, all these values are represented as a matrix $E_{best\text{-}orientation}$. In computing the energy, the corresponding value of the matrix $E_{best\text{-}orientation}$ for the angle between the searching-point and one of the next or the previous groups are obtained as the internal force for the first or end controlling point. Now, the energy function becomes as follows.

$$E=\alpha E_{continuity}+\beta E_{best\text{-}orientation}-\gamma E_{image} \quad (1)$$

B. The rest groups

Due to the traditional energy function is only considered the smoothness of the curve. For improving the performance of edge detection using snakes, the smoothness term of the intensity is also added into the energy function. It is obtained from the absolute difference of average gray-level between two lines connecting the previous and the next searching-point. It is expressed in the following:

$$E_{image\text{-}smooth} = |g_{i,j}-g_{i-1,k}|-|g_{i,j}-g_{i+1,l}|, \quad (2)$$

where $g_{i,j}$ represents the j^{th} searching-point at the i^{th} controlling-point.

Thus, the energy function may further written as

$$E=\alpha E_{continuity}+\beta[E_{space\text{-}smooth}+E_{image\text{-}smooth}]-\gamma E_{external} \quad (3)$$

(6)The minimization of energy function

Dynamic programming proposed by Amini et al.[3] is used to solve the minimization problem and find the optimal contour. Two matrices, that are the energy and position matrices, need to be computed and stored during the minimizing energy function. In computing the energy, it accumulates the energy before the group and then obtains the minimal value from the last group and their corresponding position from the position matrix. Thus, the optimal contour can be traced using the back-tracing method from the last group to the first in the position matrix. Although the dynamic programming method is computation-intensive, it can be assured that the final contour is with minimal energy.

Results and Discussion

Since some additional energy term for smoothness is added, the traditional smoothness used in Kass's algorithm is left out by setting the weighting factor as β.

6 cases of panograms are used and analyzed to evaluate the proposed image analysis system. In order to compare the accuracy, a set of data drawn manually by a experienced dentist is also obtained. Two measures such as the displacement and the similarity are defined and computed for accuracy validation.

The displacement measure is defined to compute the sum of the differences ($\triangle y$ and $\triangle x$) along the y- and x-coordinates as follows.

$$\text{Displacement} = (\triangle x + \triangle y)/N, \quad (4)$$

where N is the total number of points

The similarity measure proposed by Pinho and Almeida[6] is written in the following.

$$F_{MM} = \frac{1}{E_{ID}}\Sigma\, D_{MM}(e)$$
$$\text{where } D_{MM}(e)= \frac{1+d_{MA}-d[e,r(e)]}{1+d_{MA}+C_{MA}d[e,r(e)]} \quad (5)$$

E_{ID} represents the total number of detecting points in two matching contours. d[e,r(e)] defines the displacement between two matching contours such as the $\triangle x$ and $\triangle y$.

C_{MA} controls how fast F_{MM} decreases with displacement. d^{max}_{MA} is the permissible displacement in detecting two contours. The results are listed in Table 2 and d^{max}_{MA} is 5.

From the Table 2, the error of the displacement is

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below 2 - 7 pixels (within 3mm). An example of the detected teeth tube overlying on the panarogram is shown in Fig. 2.

Conclusion

The original snakes algorithm was proposed for a general closed-contour tracing problem. Thus, the energy for every point on the contour may be defined and computed. However the path of the teeth root tube lacked for the smoothness in some areas. For applying the concept of the active contour model into our experiment, two additional energy terms are introduced into the energy function. They are the smooth property of the intensity and the best-orientation edge. From the experimental results, the error is within the clinical acceptable range.

Since the initial curve needs to be drawn manually in this study, the performance of proposed method is dependent on selection of initial contour. In the future, it needs to investigate the method for obtaining the initial contour automatically. Besides, the placement and the number of controlling points and searching points need also to be further improved. The weighting factors are case dependent and need to be studied too.

References

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Table 1: The development environment for the proposed image analysis system

Instrument	Type
X-ray machine	Asahi Roentgen Industries Co., Ltd; AUTO 2000EXT
Scanner	Artix Scan 1800f
Computer	CPU: INTEL Pentium III 850Mhz RAM: 512M OS: WINDOWS XP
Software	Microsoft Visual C++ 6.0

Table 2: The results for accuracy evaluation

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
△ x	4.2	5.4	4.9	2.2	5.6	3.8
△ y	3.9	5.1	3.6	2.5	5.1	2.9
averag e	4.1	5.2	4.2	2.4	5.4	3.3
F_{MM}	0.35	0.15	0.40	0.55	0.23	0.44

Unit: pixels

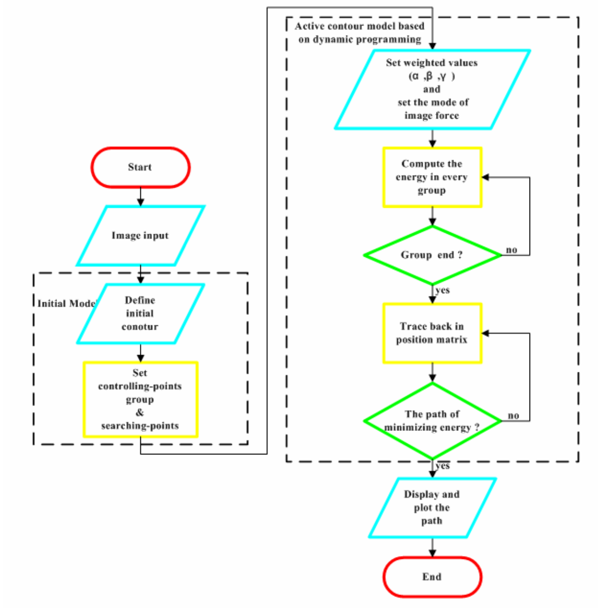

Figure 1: The flow chart of our experiment

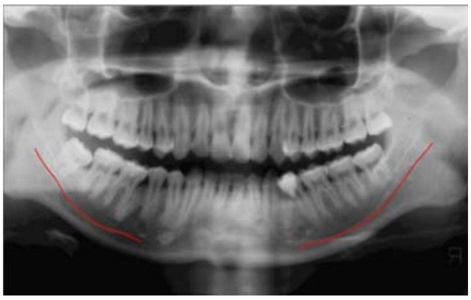

Figure 2: An example of final results