Computerized identification method for current dental intraoral radiographs based on the arranged previous dental intraoral radiographs

Akiyoshi Hizukuri[1], Ryohei Nakayama[2], Nobuo Nakako[2], Takanori Ogino[2], Hiroharu Kawanaka[1], Haruhiko Takase[1], Shinji Tsuruoka[3]

[1] Graduate School of Engineering, Mie University, Tsu, Japan
[2] Department of Radiology, Mie University School of Medicine, Tsu, Japan
[3] Graduate School of Regional Innovation Studies, Mie University, Tsu, Japan

Abstract— **Dental intraoral radiographs are saved randomly in a PACS (Picture Archiving and Communication System). Therefore, dental radiologists have to arrange manually the dental intraoral radiographs on the PACS in the interpretation of the dental intraoral radiographs. This task is bother for dental radiologists. The purpose of this study was to develop a computerized method for identifying a current image as the corresponding previous image which was taken at approximately the same position in order to arrange automatically current intraoral radiographs on the PACS based on the previous images which were arranged in the last interpretation. Our database consisted of 56 current and 56 previous dental intraoral radiographs. In our proposed method, the edges of teeth crowns were first enhanced by applying a Sobel filter in the vertical direction to images. The edges of teeth crowns were then segmented by applying a gray-level thresholding technique to the enhanced image. Approximate straight line for tops of the teeth was drawn based on a least squares method with the segmented edges. We calculated the angle between the approximate straight line and the horizontal line and rotated the original dental radiograph by an affine transformation to make the growing direction of teeth vertical. The average pixel values in the vertical direction on each x-coordinate became low between adjacent teeth because teeth regions had higher pixel values than other tissues. Therefore, individual tooth regions were divided by the vertical lines through the x-coordinates with local minimum values on the average pixel values. For all combination of current and previous images for a patient, the correlation coefficients between two images were calculated based on the pixel values after aligning images such that the number of the taken teeth becomes the same on the comparing regions. The combination of current and previous images with the highest correlation coefficient was identified as the corresponding images taken at approximately the same position. With the proposed method, identification accuracy was 80.4% (45/56). The proposed method was shown to have high identification accuracy, would be useful in the terms of the efficiency of diagnosis in the PACS.**

Keywords: **image identification, dental intraoral radiograph, follow-up images, diagnostic efficiency**

I. Introduction

In dental clinic, dental intraoral radiographs are routinely taken for assessing the effectiveness of treatment or the progress of disease [1]. An intraoral radiograph is taken by inserting a film to a patient's mouth. Fourteen intraoral radiographs are usually taken on a jaw area. These intraoral radiographs are digitized by an image scanner and are saved in PACS (Picture Archiving and Communication System). Therefore, dental radiologists need to arrange dental intraoral radiographs manually on a PACS monitor in the interpretation of the dental intraoral radiographs because these image headers do not have the information of the photography positions. This arrangement task is bother for dental radiologists. If it is possible to identify current image as the corresponding previous image which was taken at approximately the same position, current images will be arranged automatically on the PACS because the previous images were arranged in the last interpretation.

In previous studies, some investigators have developed a computerized identification method for current intraoral radiograph and the corresponding previous dental intraoral radiograph. Jain *et al.* [2] and Ito *et al.* [3, 4] specified the deceased by identifying the deceased's previous dental intraoral radiograph from the deceased's current image. Jain *et al.* compared the outline of one tooth in each of two images. Although the outline of individual tooth could be extracted accurately when the contrasts of teeth were high, the contrast near the root of teeth is usually very low in dental intraoral radiographs. It would be difficult to identify the same person's images because there often are very similar teeth in different person's image when taking into account the outline of only one tooth. Ito *et al.* used the phase information in two-dimensional discrete Fourier transformation. The identification accuracy was high when the taken teeth were the same completely in both current and previous intraoral radiographs. Although photographer tries to take an intraoral radiograph at the same position, the photograph is sometimes taken at the position shifted for one tooth or two teeth because a film is inserted manually to a patient's mouth. Therefore, it would be difficult for

Figure 1. Dental intraoral radiographs

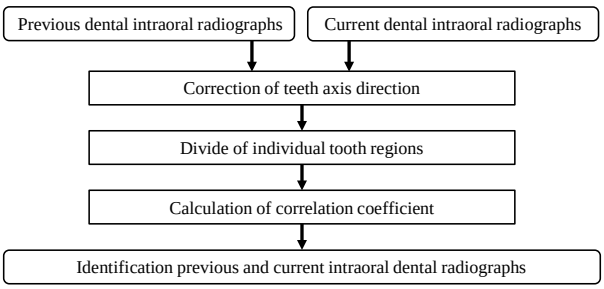

Figure 2. Schematic diagram of the proposed identification method for previous and current dental intraoral radiographs taken at approximately the same position

this method to identify the same person's images with high accuracy from such images.

To overcome the problems for these previous studies, in this study, we developed the computerized identification method for current dental intraoral radiograph and the corresponding previous intraoral radiograph by evaluating the correlation coefficients based on the area of more than two teeth between all combinations of current and previous images after aligning images such that the number of the taken teeth becomes the same in two images.

II. Materials and Methods

A. Materials

Our database consisted of 56 current and 56 previous dental intraoral radiographs that were obtained from 4 patients at the Nihon University School of Dentistry at Matsudo, Japan. The average period between previous and current radiograph examinations was 13 months. A jaw area for a patient consisted of 14 dental intraoral radiographs, as shown in Fig. 1. These radiographs were digitized with a 0.05 mm pixel size and a 8-bit gray scale by use of a scanner. The previous image corresponding to each of current images was selected by an experienced dental radiologist.

B. Methods

Figure 2 shows a schematic diagram of the proposed identification method for current and the corresponding previous dental intraoral radiographs which were taken at approximately the same position.

B.1. Correction of teeth axis direction

In dental intraoral radiography, a film is inserted manually to a patient's mouth at the different angle so that teeth being examined appear clearly on image. The intraoral radiographs for back teeth are usually portrait, whereas those for front teeth are landscape. Even if the image is taken at approximately the same position, the direction for teeth axis on the image is different slightly every radiograph examination. To correct the teeth axis direction, the edges of teeth crowns are first enhanced by applying a Sobel filter [5] in the vertical direction to images, as shown in Fig. 3(b). The edges of teeth crowns are then segmented by applying a gray-level thresholding technique [5] to the enhanced image, as shown in Fig. 3(c). Approximate straight line for tops of the teeth is drawn based on a least squares method with the segmented edges, as shown in Fig. 3(d). The approximate straight line is given by

$$y = ax + b$$

$$a = \frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n\sum_{i=1}^{n} {x_i}^2 - (\sum_{i=1}^{n} x_i)^2}, \quad b = \frac{\sum_{i=1}^{n} {x_i}^2 \sum_{i=1}^{n} y_i - \sum_{i=1}^{n} x_i y_i \sum_{i=1}^{n} x_i}{n\sum_{i=1}^{n} {x_i}^2 - (\sum_{i=1}^{n} x_i)^2}. \quad (1)$$

Here, x_i and y_i show the coordinates on the segmented edges, whereas n shows the number of segmented pixels as the edge. We calculate the angle between the approximate straight line and the horizontal line and rotate the original dental radiograph by an affine transformation [5] to make the teeth axis direction vertical. The affine transformation is define as

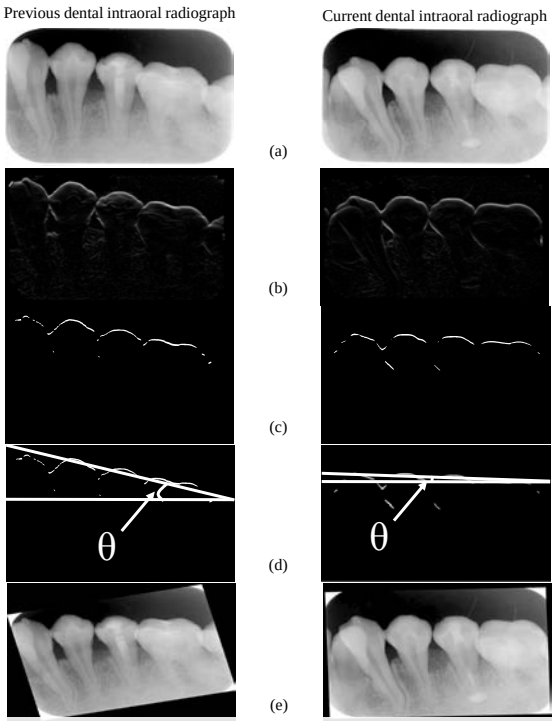

Figure 3. Correction of teeth axis direction: (a) original image, (b) Enhanced edges of teeth crowns, (c) Segmented edges of teeth crowns, (d) Approximate straight line, (e) Rotation of dental intraoral radiograph

$$[x' \quad y' \quad 1] = [x \quad y \quad 1] \cdot \begin{bmatrix} cos\theta & sin\theta & 0 \\ -sin\theta & cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} . \qquad (2)$$

Figure 3(e) shows the image rotated by applying the correction of the teeth axis direction.

B.2. Divide of individual tooth regions

Teeth appear as regions which have higher pixel values than other tissues in the intraoral radiographs. Therefore, the average pixel values in the vertical direction on each x-coordinate would become low between adjacent teeth. Figure 4(b) shows the average pixel values in the vertical direction on each x-coordinate. Individual tooth regions are divided by the vertical lines through the x-coordinates with local minimum values on the average pixel values, as shown in Fig. 4(c).

B.3. Calculation of correlation coefficient

For a patient, we combine all pairs of each current image and 14 previous images. Two images are aligned by shifting the image by the unit of area for one tooth such that the number of the taken teeth becomes the same on the comparing regions, as shown in Fig. 5. Here, we give the condition that the comparing regions must have area for more than two teeth. The correlation coefficient between two

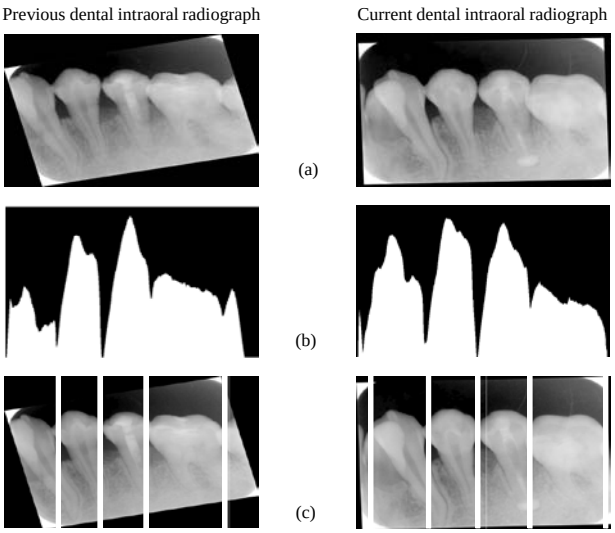

Figure 4. Divide of individual tooth regions: (a) Rotated dental intraoral radiograph, (b) Average pixel values on each X-coordinate, (c) individual divided tooth regions

images is calculated based on the pixel values on the comparing regions. Note that more than one correlation coefficient is calculated for a pair of current and previous images. The correlation coefficient is defined as

$$r = \frac{\Sigma\Sigma\left[\{f(x,y) - \overline{f(x,y)}\} \cdot \{g(x,y) - \overline{g(x,y)}\}\right]}{\sqrt{\Sigma\Sigma\{f(x,y) - \overline{f(x,y)}\}^2} \cdot \sqrt{\Sigma\Sigma\{g(x,y) - \overline{g(x,y)}\}^2}} . \qquad (3)$$

$f(x,y)$ is a pixel value on the comparing region in a current image, wheares $g(x,y)$ is the corresponding pixel value on the comparing region in a previous image. $\overline{f(x,y)}$, and $\overline{g(x,y)}$ shows the average pixel value for $f(x,y)$ and $g(x,y)$, respectively. The highest correlation coefficient is defined as the correlation coefficient for the pair.

B.4. Identification of images

For each current image, previous image with the highest correlation coefficient is identified as the corresponding images taken at approximately the same position. If the same previous image is identified as the corresponding image for more than two current images, the current image with higher correlation coefficient is selected.

III. RESULT AND DISCUSSION

We obtained the identification accuracy of 80.4% (45/56) by applying the proposed method to our database. One of

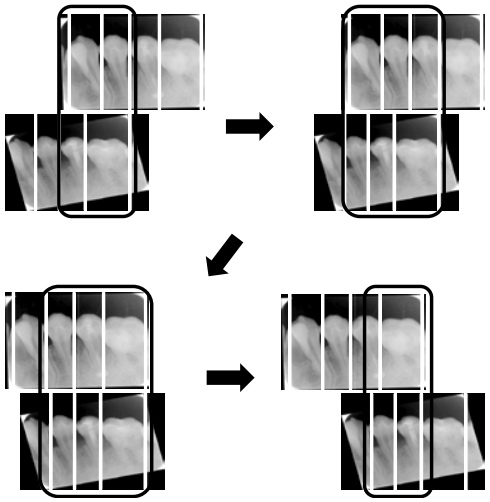

Figure 5. Calculation process of correlation coefficient

the features of the images which were not identified correctly was that the same more than one tooth appeared in two adjacent intraoral radiographs. This was sometimes seen in the images taken near back teeth. Even if the previous image did not correspond to the current image, the correlation coefficient would be high when regions which contained the same teeth were selected as the comparing regions. Figure 6(a) shows the image taken at the second position from the right, whereas Fig. 6(b) shows the image taken at the most right position. The same teeth exist on the right in Fig.6 (a), whereas those exist on the left in Fig.6 (b). Therefore, it might be possible to solve this problem by taking into account the location of the comparing region in image. Another feature was a treated tooth between previous and current radiograph examinations. In general, an inlay made of metal is used to treat a cavity. The inlay appears as region with very high pixel values in the intraoral radiographs. Therefore, the correlation coefficient is influenced greatly from the inlay and would become low because that is calculated based on the pixel values. This problem will be solved by removing the inlay region from the comparing regions for calculating the correlation coefficient.

The proposed method was developed as the purpose of arranging the intraoral radiographs automatically on the PACS. It is easy to apply the proposed method to the computerized method for specifying the deceased by identifying the deceased's previous dental intraoral radiograph from the deceased's current image. In this application, the feature that the same more than one tooth appeared in two adjacent intraoral radiographs will be an advantage to improve in the accuracy of specifying the

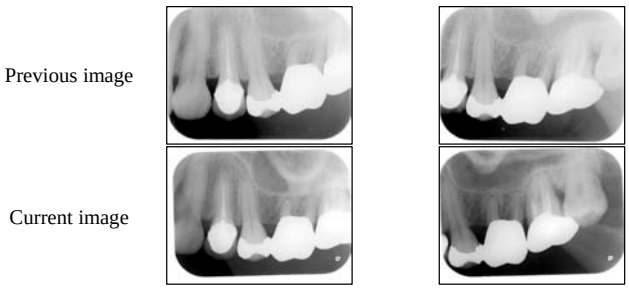

Figure 6. Same three teeth appeared in two adjacent intraoral radiographs.

deceased. The proposed method can also align the same teeth in current and previous images. Subtle change over time in normal tissue would become clear by subtracting the pixel values between the current image and the aligned previous image. This implies that it is possible to enhance early cavity and early disease in the subtracted image. In further study, we will examine these applications.

IV. Conclusions

In this study, we developed the computerized method for identifying a current dental intraoral radiograph as the corresponding previous dental intraoral radiograph which was taken at approximately the same position. By applying the proposed method to our database, we obtained the identification accuracy of 80.4% (45/56). The proposed method was shown to have high identification accuracy, would be useful in the terms of the efficiency of diagnosis in the PACS.

References

[1] T.M. Lehmann, H.-G.Grondahl, D.K.Benn, "Computer-based registration for digital subtraction in dental radiology", Dentomaxillofacial Radiology, vol.29, pp.323-346, 2000.

[2] A.K.Jain, H.Chen, "Matching of dental X-ray images for human identification", Pattern Recognit, vol.37, no.7, pp.1519-1532, 2004.

[3] K.Ito, A.Nikaido, T.Aoki, E.Kosuge, R.Kawamata, I.Kashima, "A Dental Radiograph Recognition System Using Phase-Only Correlation for Human Identification", IEICE., vol.E91-A, no.1, pp.298-305,2008.

[4] K.Ito, A.Nikaido, T.Aoki, E.Kosuge, R.Kawamata, I.Kashima, "A High-Accuracy Image Registration Algorithm Using Phase-Only Correlation for Dental Radiographs", IEICE.,vol.J91-D, no.7, pp.1788-1797,2008,(in Japanese).

[5] R.C.Gonzales, R.E.Woods, " Digital Image Processing", MA: Addison-Wesley, 1992.