A new digital intraoral X-ray image analysis system for objective personal identification

Abstract

Objectives. To develop a new image processing system for personal identification that applies phase-only correlation (POC) to digital intraoral X-ray images.

Methods. We developed a personal identification analysis system that applies POC. Amplitude components were extracted by applying fast Fourier transform to digital intraoral X-ray image data. The amounts of rotation and magnification of the images was transformed into a translational shift via image processing of the obtained amplitude components. The position shift of the images caused by these translational shifts was corrected by applying POC to the images after the rotation and magnification were corrected. The accuracy of the system was evaluated visually by using digital image subtraction images of the reference image and a comparison image processed by the system.

Results. The results showed that this system corrects the position of the images for translational shift and rotational displacement. The magnification of images caused by the translational shift of the imaging plate was also corrected to within a specific admissible range. The system has a wide tolerance for images with density differences.

Conclusions. This image processing system is effective for objective personal identification.

Key words Personal identification · Forensic dentistry · Registration · Phase-only correlation · Dental radiography

Introduction

Victims of disasters and accidents are sometimes extremely difficult to identify if they have been severely disfigured. In such cases, information obtained from the teeth of a person can be used for personal identification, and in particular, antemortem dental X-ray images are very useful. These durable images may be available on record after many years and clearly show unique personal characteristics such as the shape and position of the teeth and their condition. We experienced difficulty identifying victims after an aviation disaster in 1985, in which a Japan Airlines jumbo jet crashed into Mt. Osutaka in Gunma Prefecture, Japan. The dentists who participated in identifying the victims required a very long time to examine the oral cavity and obtain radiographs of the victims’ jaws, and to collect and sort their dental records. The dentists also invested a great deal of labor in checking the dental information taken from the victims against dental records. This experience gave impetus to develop a system to enable faster and more accurate personal identification of victims in disasters or accidents.1–3

Currently, personal identification from X-ray images of the jaw and oral cavity is evaluated subjectively. An objective evaluation method needs to be developed in which the evaluator compares postmortem and antemortem X-ray images, and evaluates based on identification of the teeth in two sets of images from the same person. Since the images may not be standardized, it is difficult to make a judgment based on X-ray images taken at different times and places. Considering such difficulties, attention has focused on the development of methods to permit objective personal identification based on the comparison of two intraoral X-ray images. This study examines the practical possibilities of a new personal identification method that applies phase-only correlation (POC)4,5 to intraoral X-ray images.

Materials and methods

Personal identification analysis system

Figure 1 shows block diagrams of the personal identification analysis system. Figure 1A illustrates how rotation- and scale-invariant phase-only correlation (RSIPOC) corrects for image rotation and magnification, and Fig. 1B shows
how POC corrects for the image position shift caused by translational displacement. A circular (180-pixel diameter) region of interest (ROI) is set at the center of the reference image $O_A(x,y)$. The reference image $O_B(x,y)$ is obtained from $O_A(x,y)$ after rotation, magnification, and a translational shift. By using a fast Fourier transform (FFT), the amplitude images (two-dimensional power spectrum images) $P_A(u,v)$ and $P_B(u,v)$ are obtained from the generated digital image of the ROI. The horizontal and vertical axes indicate the spatial frequency of the generated image, and the density denotes the spectrum intensity of each spatial frequency. Consequently, the spectrum components are shown in the images as a density distribution. Here, images $P_A(u,v)$ and $P_B(u,v)$ are rotated only by the amount of rotation in the original, that is, independently of the location of the center of rotation. For this process, images $P_A(u,v)$ and $P_B(u,v)$ are each transformed from rectangular coordinates $u,v$ into polar coordinates $r,\theta$. In other words, the angle of rotation can be transformed into a translational shift by transforming the amplitude image coordinates into polar coordinates. In addition, the change in magnification can be transformed into a translational shift along the $r$ axis by performing logarithmic sampling of the $r$ axis of the polar coordinates when transforming the amplitude images into polar coordinates. Phase spectrum images $F_A(u,v)$ and $F_B(u,v)$ are obtained by performing another FFT of images $P_A(r,\theta)$ and $P_B(r,\theta)$. A synthesized phase spectrum $F^*(u,v) \times F_B(u,v)$ can then be determined from these phase spectrums. Then, a RSIPC is performed by applying an inverse FFT to the synthesized phase spectrum. The peak coordinates in the RSIPC represent the scale and rotation variation between the two compared images. In short, the amount of rotation is represented by the displacement in the $\theta$ direction, and the degree of magnification is represented by the displacement in the log $\theta$ direction.

In Fig. 1B, the adjusted image $O_B'(x,y)$ is obtained by performing a correction based on the amount of rotation and the degree of magnification obtained from the calculation. The ROI is then set up again on image $O_B'(x,y)$ with the corrected rotation and magnification, and on the reference image $O_A(x,y)$. Phase spectrum images $F_A(u,v)$ and $F_B'(u,v)$ are obtained by FFT. Convolution of the phase spectrum images results in the synthesized phase spectrum $F^*(u,v) \times F_B'(u,v)$. Then, the POC is obtained by inverse FFT.