Personal Identification Using Teeth Images

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Abstract:
This paper presents a personal identification method using teeth images. The method uses images for teeth expressions of anterior and posterior occlusion state and LDA-based technique. Teeth images give merits for recognition because teeth, rigid objects, cannot be deformed at the moment of image acquisition. In the experiments, personal identification for 12 people was successful. It was shown that our method can contribute to multi-modal authentication systems.

Keywords: Biometrics, Linear discriminant analysis (LDA), Nearest neighbor (NN) algorithm, Pattern recognition, Personal identification, Teeth recognition.

1. INTRODUCTION

Biometrics[1] can be used for personal identification for securities such as gate entrance, bank ATM, mobile system, computer system, etc. Biometrics is categorized into two methods: one is using physical feature such as finger print, hand vein, iris, face, etc. and the other is by behavioral feature such as signature, voice, foot step, etc. The biometric systems can be used to two kinds of applications of verification and identification. Identification is to search an object on the predefined database, while verification is to decide whether a user is oneself or not.

Current available useful biometric measurements for personal authentication are face, fingerprint, iris, hand vein, etc[1]. Iris recognition requires a high resolution image acquisition equipment. Fingerprint can be easily contaminated with other materials such as sweat, dust, etc. Face and hand vein can be often deformed by inconsistent poses of a user.

This paper proposes a personal identification method using teeth images. The method is composed of teeth image acquisition and teeth recognition in which there are teeth region extraction and pattern recognition procedure in a sequential step. In the teeth recognition, an input pattern is compared with each pattern of the teeth database in which each class has feature vectors for teeth set of a person. The method uses teeth images for anterior and posterior occlusion state. For pattern recognition, we use LDA (linear discriminant analysis)-based method[2-4] which is popular in appearance-based face recognition and a nearest neighbor (NN) algorithm[5]. In general, teeth cannot be deformed at the moment of image acquisition because they are rigid objects. This factor allows the image processing to be easily handled. In addition, teeth can give information of age of a person. Teeth recognition does not require high resolution images and can use a small camera module, so that it can be implemented with low cost. Reports on teeth recognition for personal identification have not been found. Our method can contribute to multi-modal authentication systems.

2. TEETH IMAGE ACQUISITION

In general, human being has 32 permanent teeth, which are embedded to the upper (maxillary) and lower (mandibular) gingival body as shown in Fig. 1. Typically, the upper anterior teeth are larger than the lower ones, canines are longer than incisors, and central incisors are larger than lateral incisor in the upper teeth.

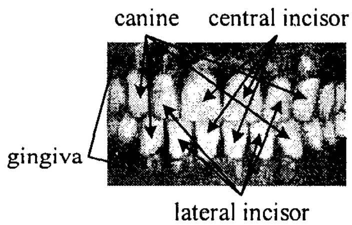
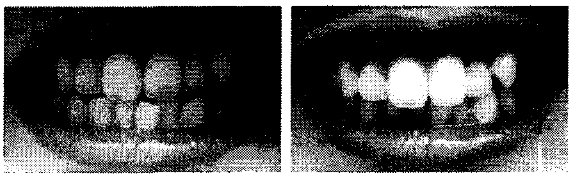


Fig. 1. Frontal view and names of typical foremost anterior teeth.

Teeth images can be acquired with the digital camera, although without high resolution, of a dedicated personal identification system, a personal computer, or other devices. Teeth images may be acquired under constraints such as illumination and teeth expression at the moment which personal identification is needed. The teeth images are grabbed for the frontal views of the anterior teeth. The teeth expressions are anterior and posterior teeth occlusion state as shown in Fig. 2. It is recommended that the frontal gingival body near the anterior teeth is appeared at the image acquisition in each expression.



(a) (b)

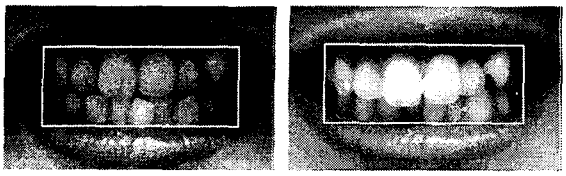
Fig. 2. Two different states of teeth expressions in acquiring teeth image: (a) anterior teeth occlusion, (b) posterior teeth occlusion.

3. TEETH RECOGNITION

Our teeth recognition is using an appearance-based method[2-4]. Teeth recognition procedure consists of teeth region extraction and pattern recognition in sequential steps. An input teeth pattern is projected by LDA and matched with each pattern of the database containing teeth feature vectors of people.

3.1. Teeth Region Extraction

Teeth region in the image is the rectangle bounding frontal view of the anterior teeth as shown in Fig. 3.



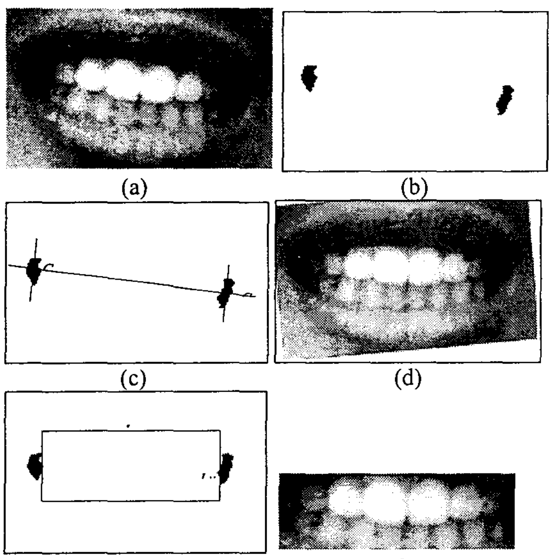
(a) (b)

Fig. 3. Teeth region, depicted as the white rectangle, of frontal view of the anterior teeth in the image: (a) anterior teeth occlusion, (b) posterior teeth occlusion.

The region can be extracted by thresholding in the image because the teeth and their both sides are usually bright and dark, respectively. The thresholding is performed as Eq. (1),

$$g(x)=\begin{cases}1, f(x)\le T\\ 0, f(x)>T\end{cases} \qquad (1)$$

where $f(x)$ is the value of the intensity or H component of HSI (Hue Saturation Intensity) color space[6] at the position x in the image. The thresholding gives both sides of teeth as shown in Fig. 4 (b). The centers of mass[7], C_L and C_R, of the teeth sides are obtained as shown Fig. 4 (c). The image is rotated to make the line connecting the centers horizontal. Figure 4 (d) is the result aligned to the horizontal line.



(a) (b) (c) (d) (e) (f)

Fig. 4. Teeth region extraction procedure: (a) acquired teeth image, (b) thresholded image, (c) the centers of mass, (d) image rotated to make the line connecting the centers horizontal, (e) the box bounding the teeth region, (f) extracted teeth region.

The bounding rectangle is extracted by drawing a box between both sides of teeth in the rotated image as shown in Fig. 4 (e). The rectangle is composed of horizontal lines along the line interconnecting the centers of mass and vertical lines defined as $L_H = RL_V$, where R is ratio between the horizontal and vertical length. The teeth region is extracted according to the rectangle as shown in Fig. 4 (f) and Fig. 5.

3.2. Pattern Recognition

The normalized teeth region extracted in the previous step is projected to LDA space[2-4]. And the projected image is matched to each pattern of the database. Each person has different characteristics in appearance of the anterior and posterior occlusion as well as the teeth.

LDA searches for feature vectors in the underlying space that best discriminate among classes rather than those that best describe the data. More formally, given a number of independent features relative to which the data is described, LDA creates a linear combination of these which yields the largest mean differences between the desired classes. For all the samples of all classes, two measures are defined. The between-class scatter matrix is defined as Eq. (2),

$$S_B=\sum_{i=1}^{c} N_i(\mu_i-\mu)(\mu_i-\mu)^T \qquad (2)$$

and the within-class scatter matrix is depicted as

$$S_W=\sum_{i=1}^{c}\sum_{x_k\in X_i}(x_k-\mu_i)(x_k-\mu_i)^T \qquad (3)$$

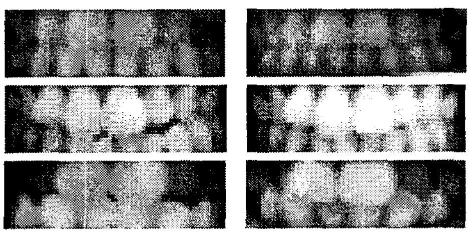
where μ_i is the mean image of class X_i and N_i is the number of samples in class X_i. If S_W is nonsingular, the optimal projection W_{opt} is chosen as the matrix with orthonormal columns which maximizes the ratio of the determinant of the between class scatter matrix of the projected samples to the determinant of the within-class scatter matrix of the projected samples,

$$W_{opt}=\arg\max_{W}\frac{|W^T S_B W^T|}{|W^T S_W W^T|} = [\mathbf{w}_1\mathbf{w}_2\ldots\mathbf{w}_m] \qquad (4)$$

where $\{\mathbf{w}_i \mid i=1,2,\ldots m\}$ is the set of generalized eigenvectors of S_B and S_W corresponding to the m largest generalized eigenvalues $\{\lambda_i \mid i=1,2,\ldots m\}$,

$$S_B\mathbf{w}_i=\lambda_i S_W \mathbf{w}_i,\ i=1,2,\ldots m \qquad (5)$$

where there are at most $c-1$ nonzero generalized eigenvalues, and so an upper bound on m is $c-1$, where c is the number of classes.



(a) (b)

Fig. 5. Normalized teeth regions of the teeth database: (a) anterior teeth occlusion, (b) posterior teeth occlusion.

For classification of the projected feature vectors, we uses a nearest neighbor (NN) algorithm[5] which is one of the popular minimum-distance classifiers in pattern recognition.

4. EXPERIMENTAL RESULTS

For the experiments, teeth images for 12 people were acquired by the digital camera embedded to a mobile phone under constraints such as illumination and teeth expression. The camera has image resolution of 352×288 in pixels. Teeth regions were extracted in the images and normalized to the image with the size of 20×60 in pixels, where $L_H / L_V = 3$, as shown in Fig. 6. By applying LDA algorithm to the normalized teeth region images, the projected feature vectors were achieved and stored to the database.

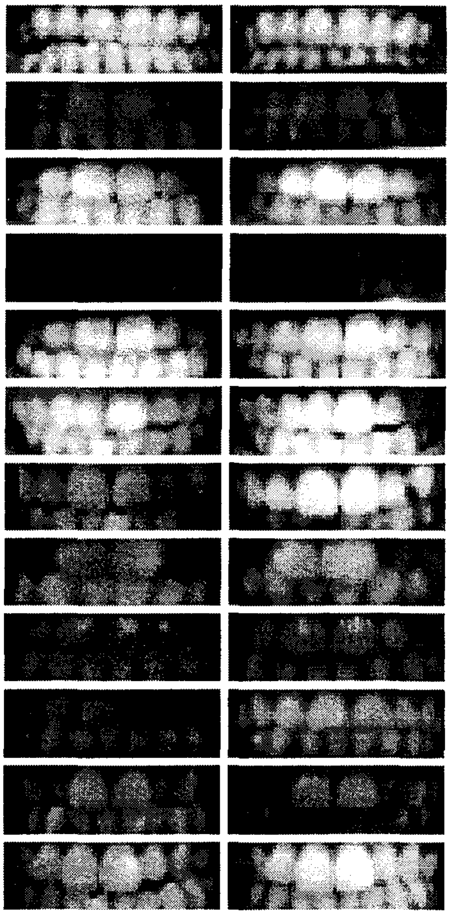
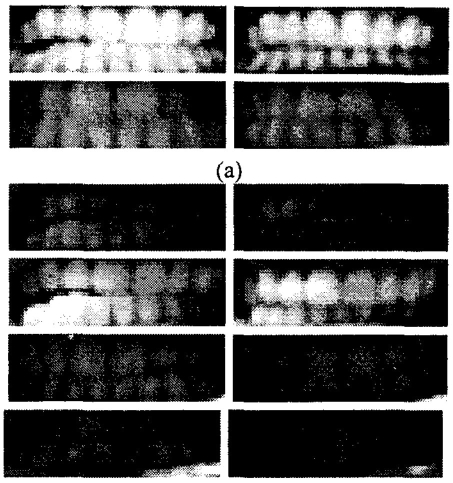


Fig. 6. Teeth regions with anterior (left) and posterior (right) occlusion teeth expression for 12 people are normalized.

For all the samples, the matching procedure by NN algorithm was performed with the feature vectors on the database. The results for 12 people were successful in teeth recognition for personal identification. From this result, it was found that our method can be another modality for biometrics.

As appearance-based techniques commonly do, free constraint of illumination and teeth expression can deform teeth patterns as shown in Fig. 7. For the cases, our method could not correctly find corresponding pattern on the database. Consistent teeth expressions of a person can reduce error rate in teeth recognition.



(a)

(b)

Fig. 7. Some cases are difficult to recognize corresponding pattern on the database under free constraint of illumination and teeth expression: (a) teeth patterns of database, (b) recognition-failed patterns corresponding to (a).

5. CONCLUSION

This paper presents a personal identification method using teeth images. The method uses images for teeth expression of anterior and posterior occlusion state and LDA-based technique. In the experiments, personal identification for 12 people was successful. It was shown that our method can contribute to multi-modal authentication systems.

Teeth images give merits for recognition because teeth, rigid objects, cannot be deformed at the moment of image acquisition. But, teeth expression can be affected by lip pose, occlusion of the upper and lower teeth, and illumination. In the future, our method will be tested for more people with various teeth expression. Also, further study for the algorithm to overcome various expressions will be performed.

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