CORRELATION-BASED THUMBPRINT IDENTIFICATION

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Abstract
Correlation-based techniques match the global pattern of ridges and furrows to determine whether the ridges align. Instead of using minutiae locations, grayscale information from fingerprint image is used in correlation-based matching. Correlation-based technique overcomes some of the limitations of minutiae-based matching. The primary advantage of correlation-based matching is that it is capable of dealing with bad quality images from which no minutiae can be reliably extracted. In this paper, the robustness of Rao's algorithm in producing reliable directional images is explored further in correlation-based thumbprint matching scheme. Experiments have shown that the performance is satisfactory at this moment compare to other fingerprint identification system.

1. INTRODUCTION

Thumbprint identification plays a vital role in personal identification especially in today's world. It is a developing field which attracts attentions of many researchers. Identity authentication is a crucial element in the assurance of security control system. Thumbprint identification or recognition is preferred over PIN numbers, keys and passwords. This is mainly due to the fact that the particular authorized person must be physically present for identification purpose to ensure security. Numerous algorithms have been proposed and have their strong points and limitations.

Fingerprints are graphical flow-like ridges and furrows or valleys present on human fingers. Their formations depend on the initial conditions of the embryonic mesoderm from which they develop [5]. The ridge-valley structures are the main source for the information to be extracted from fingerprints [2]. Thumbprint identification identifies whether a query fingerprint is present in the database and retrieves the most similar from database [4]. There are two levels of details in fingerprint for identification, minutiae and directional field. Fingerprint matching techniques can be placed into two categories: minutiae-based and correlation-based. Minutiae-based relies entirely on mapping the complete print, while correlation-based works on the gray-scale information of the print. Minutiae are commonly used for matching, which is a one-to-one comparison of two fingerprints. The main shortcoming is difficult to extract minutiae points accurately when the fingerprint is of low quality. The matching is largely influenced by the quality of the detection and segmentation of the minutiae. In noisy fingerprints, many false minutiae are extracted, decreasing the matching performance.

Straightforward matching between fingerprint pattern to be identified is not suitable for reliable matching due to its high sensitivity to errors. Errors are due to various noises, damaged fingerprint areas, or the finger being placed in different areas of fingerprint scanner window and different orientation angles, as well as finger deformation during the scanning procedure.

2. ORIENTATION

A directional image is a transformed image, which defines the orientations of pixels [3]. There is no preprocessing being implemented in this paper in order to preserve the information of raw thumbprint images. Smoothing, sharpening, thinning and thresholding of an image may result in lost of data. Smoothing aims to suppress noise or other small fluctuations in the image equivalent to the suppression of high frequencies in the frequency domain. However, smoothing also blurs all sharp edges that bear important information about the image. The implementation of Sobel operator eliminates the need for preprocessing. Thumbprints being tested in this paper are of good quality, however, they may suffer from a small amount of translation and rotation of not more than 30° from manual inspection.

Two convolution kernels form the gradient based Sobel edge operator. One kernel, G_x corresponds maximally to a generally horizontal edge and the other kernel, G_y corresponds to a vertical edge. Sobel edge enhancement operation extracts all edges in an image regardless of direction. The two kernels are being used in order to obtain gradient G_x and G_y which would be used in Rao's algorithm. Rao divides input fingerprint into blocks or windows of size W × W [5]. The direction of a block $\theta(i,j)$ is decided using precomputed gradients of pixels in the block, G_x and G_y [1]. The local orientation at each pixel (i,j) is estimated using equations (1), (2) and (3).

$$V_x(i,j) = \sum_{u=i-w/2}^{i+w/2} \sum_{v=j-w/2}^{j+w/2} 2G_x(u,v)G_y(u,v) \qquad (1)$$

$$V_y(i,j) = \sum_{u=i-w/2}^{i+w/2} \sum_{v=j-w/2}^{j+w/2} (G_x^{\,2}(u,v) - G_y^{\,2}(u,v)) \qquad (2)$$

$$\theta(i,j) = \frac{1}{2}\tan^{-1}\left[\frac{V_x(i,j)}{V_y(i,j)}\right] \qquad (3)$$

where W is the size of the local window, G_x and G_y are the gradient magnitudes in x and y directions, respectively. $\theta(i,j)$ represents the local ridge direction at pixel (i,j).

The orientation field is used to compute the optimal estimate of the direction vectors at each pixel in a window. If either $G_x(u,v)$ or $G_y(u,v)$ is zero, then the estimate of the dominant direction is trivial (0° or 90°)[6]. The angle $\theta(i,j)$ is quantized into 8 directions to facilitate further computation. Quantized directions are shown in Fig. 2.

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \qquad G_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

Figure 1. Sobel edge operator

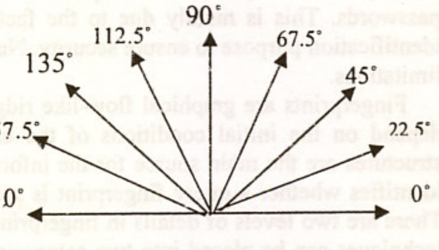

Figure 2. Quantized Directions

3. MATCHING

Mean Squared Error (MSE) is the technique used to evaluate whether an image, $A(x_1,y_1)$ matches the other image, $B(x_1,y_1)$. MSE is applicable in this paper to determine the relative difference between two images. Assume image *A* is an image obtained from query thumbprint image and image *B* is an image stored in a database. The MSE is given by the following equation:

$$MSE = \frac{1}{M \times N}\sum_{i=1}^{M}\sum_{j=1}^{N} | A(x_{1i}, y_{1i}) - B(x_{2i}, y_{2i}) | \qquad (4)$$

M denotes the number of pixels in x-direction, and N denotes the number of pixels in y-direction.

Patterns of a directional image, $A(x_1,y_1)$ are compared with a list of templates that are stored as pattern representations, $B(x_1,y_1)$. A predetermined value of mean squared error is determined. Comparison is done by the computation of MSE. The best match below the predefined value of mean squared error is recognized as the identified and match image. If none of the matches fulfill this condition, the image is rejected and being categorized as no match found.

4. EXPERIMENTAL RESULTS

The proposed matching algorithm has been tested on a database, which consists of 27 individuals for a total of 135 thumbprint images (whorl, left loop and right loop) and a total of 20 thumbprint images (whorl, left loop, right loop, arch and tented arch) from other individuals. A total of 155 thumbprint images (49 whorl images, 54 left loop images, 44 right loop images, 4 arch images and 4 tented arch images) are tested. The size of these 256 gray-scale images is 256×256 pixels in dimension. Some of the images may suffer from a small amount of translation and rotation of not more than 30° from manual inspection. The thumbprint images in the database are of reasonable quality. Keyword "query database" refers to query images to be matched with dataset, whereas "dataset" is the keyword of directional images in database (templates). Examples of directional images, which are the quantized orientation field obtained from the proposed matching algorithm is shown in Figure 3.

In a biometrics system operating in an identification mode, there are four possible outcomes: genuine acceptance (Successful Acceptance Rate – SAR), imposter rejection (Successful Rejection Rate – SRR), genuine rejection (False Rejection Rate – FRR), and imposter acceptance (False Acceptance Rate – FAR). The first and the second outcomes are correct while the third and the fourth outcomes are errors.

The experiment in this program is done on a computer, with Pentium III processor and 128MB RAM. The matching rate is 94.53%, overall False Acceptance Rate (FAR) is 3.13%, overall False Rejection Rate (FRR) is 2.34% and overall average processing time is 1.00 second. FAR and FRR are mainly due to the poor image quality, including missing area, rotation and translation. This matching algorithm is able to tolerate rotation of not more than 10°.

Table 1: Comparison of Matching Algorithm

Matching Algorithm	Reference Number	Number of Test Set images	Matching Rate
Rao's Algorithm	(This paper)	155	94.53%
Rao's Algorithm in orientation estimation	[5]	490 (MSU)	92.83%
	[6]	100 (NIST9)	80.00%
Wavelet Transform	[7]	150	98.00%
	[8]	890	97.50%
Filterbank-Based	[9]	2672 (MSU-DB1)	92.58%
Minutiae	[10]	900 (IBM-HURSLEY)	87.00%

The similarity between [5], [6] and this proposed matching algorithm is the use of Rao's algorithm in orientation field estimation explained in Section 2. As clearly stated in the table, matching rate for [5] is 92.83% by using MSU (490 images vary in quality) while for [6] is 80% by using NIST9 (100 images). In [7], two stages wavelet transform is utilized in constructing a fingerprint directional image and the matching rate is 98%. From [8], which is implemented using wavelet transform, the matching rate is 97.5% (using 890 images of unknown quality). As clearly stated in [9], which is implemented filterbank-based matching, the matching rate is 92.58% when MSU_DBI (2672 images vary in quality) is used. From the result of [10], which is a minutiae matching, 87% matching rate is obtained when using IBM_HURSLEY (900 images of unknown quality). This is only a coarse level comparison due to many differences in the matching algorithm, query database, dataset and implementation methods.

5. CONCLUSIONS

According to the statistical analysis from experimental results, this matching algorithm is quite fast and precise. Images which are stored as dataset images are images from whorl, left loop and right loop categories. This is due to the fact that majority of the people have thumbprints from these three categories. Since the database consists of thumbprint images from five common fingerprint categories, it can be concluded that this thumbprint identification program is able to match thumbprints from all fingerprint categories. To improve the efficiency of the proposed matching, a coarse level thumbprint classification can be implemented before matching process to obtain even shorter processing time. Image enhancement could be done incorporate in feature extraction to improve the quality of poor images.

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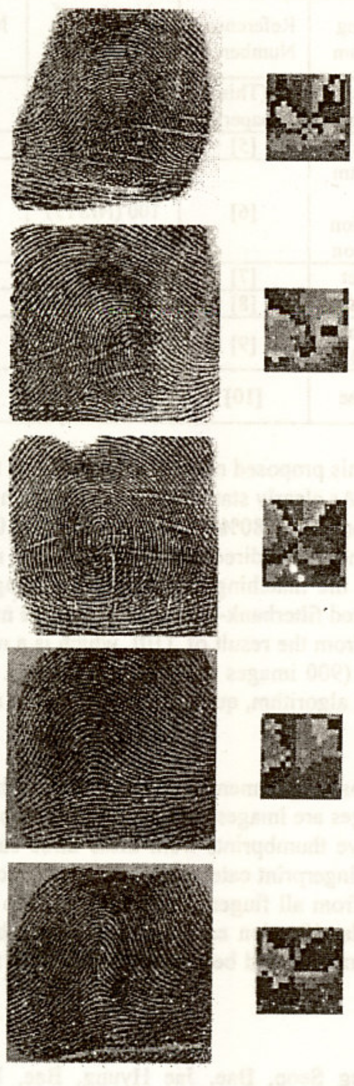

Figure 3. Raw Thumbprint and Resulting Directional Image