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Fingerprint Feature Extraction Algorithm

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ABSTRACT
The goal of this paper is to design an efficient Fingerprint Feature Extraction (FFE) algorithm to extract the fingerprint features for Automatic Fingerprint Identification Systems (AFIS). FFE algorithm, consists of two major subdivisions, Fingerprint image preprocessing, Fingerprint image postprocessing. A few of the challenges presented in an earlier are, consequently addressed, in this paper. The proposed algorithm is able to enhance the fingerprint image and also extracting true minutiae.
Keywords: *Biometrics, Fingerprint Enhancement, Multistage Median Filter (MMF), Top & Miss Transformation, Minutiae*

I. INTRODUCTION

Biometrics is the science of identifying or verifying the identification of a person based on unique physiological and behavior characteristics. Fingerprints were accepted formally as valid personal identifier in the early twentieth century and have since then become a de-facto authentication technique in law enforcement agencies worldwide. The FBI currently maintains more than 400 million Fingerprint records on file. Fingerprints have several advantages over other biometrics, such as following: Highly universality, Highly distinctiveness, High permanence, Easy collect ability, High performance, Wide acceptability.

However, verification usually relies exclusively on minutiae features. Most automatic systems for fingerprint comparison are based on minutiae matching. Minutiae are local features marked by ridge discontinuities. There are about 18 distinct types of minutiae features that include ridge endings, bifurcation, crossovers and islands. Minutiae are minute details of the fingerprint and they are shown in Fig.1.Automatic minutiae detection is an extremely critical process, especially in low quality fingerprints were noise and contrast deficiency can originate pixel configurations similar to minutiae or hide real minutiae. A ridge ending occurs when the ridge flow abruptly terminates and a ridge bifurcation is marked by a fork in the ridge flow.

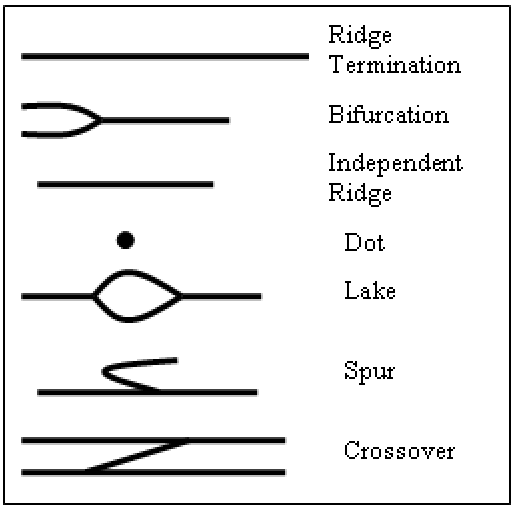


Fig.1. Minutiae Types

Most matching algorithms do not even differentiate between these two types since they can easily get exchanged under different pressures during acquisition.

In this paper, multiple sources of information are consolidated to enhance the performance of automatic fingerprint identification systems. A critical step in automatic fingerprint matching is to automatically and reliably extract minutiae from the input fingerprint images. However, the performance of a minutiae extraction algorithm relies heavily on the quality of the input fingerprint images. In order to ensure that the performance of an automatic fingerprint identification/verification system will be robust with respect to the quality of the fingerprint images, it is essential to incorporate a fingerprint enhancement algorithm in the minutiae extraction module. To deal with this, the proposed Fingerprint Feature Extraction algorithm will perform

Preprocessing method and Post processing method. A series of image enhancement is applied to the fingerprint image in Preprocessing method. With the use of enhanced fingerprint image, extract the true minutiae points in Post processing method

The Paper is organized as follows. Preprocessing method is presented in Section 2, Post processing method is presented in Section 3.

II. PREPROCESSING

In this section, a series of process is applied to the fingerprint image.

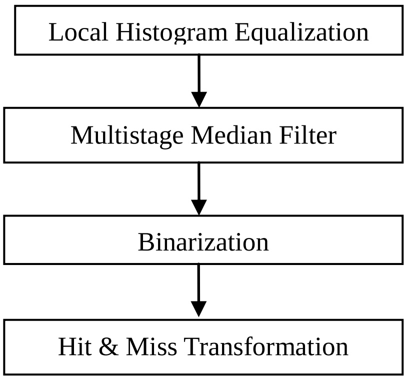


Fig.2. Steps involved in Preprocessing

Local histogram equalization is used for contrast expansion and Multistage Median Filtering(MMF) for noise reduction. The binarization process is applied by adaptive thresholding based on the local intensity mean. Thinning is done using morphological thinning operation, Hit and Miss Transformation.

2.1 LOCAL HISTOGRAM EQUALIZATION:

Histogram equalization defines a mapping of gray level p into gray levels q such that the distribution of gray level q is uniform. The mapping stretches the contrast (expands the range gray levels) for gray levels near the histogram maximum. Since contrast is expanded for most of the image pixels, the transformation improves the detect ability of many image features. The probability density function of a pixel intensity level k , r is given by the equation,

$$p_r(r_k) = \frac{n_k}{n} \qquad (2\text{-}1)$$

Where: 0<= r_k , k=0,1,2…255,. n_k is the number of pixels at intensity level r_k and n is the total number of pixels. The histogram is derived by plotting $p_r(r_k)$ against r_k . A new intensity s_k of level k is defined as:

$$s_k = \sum_{j=0}^{k} \frac{n_j}{n} = \sum_{j=0}^{k} p_r(r_j) \qquad (2\text{-}2)$$

We apply the histogram equalization locally by using a local window of 11x11 pixels. This results in expanding the contrast locally, and changing the intensity of each pixel according to its local neighborhood. Figure 2.1 (right) present the improvement in the image contrast obtained by applying the local histogram equalization. Histogram equalization is to expand the pixel value distribution of an image so as to increase the perceptional information.

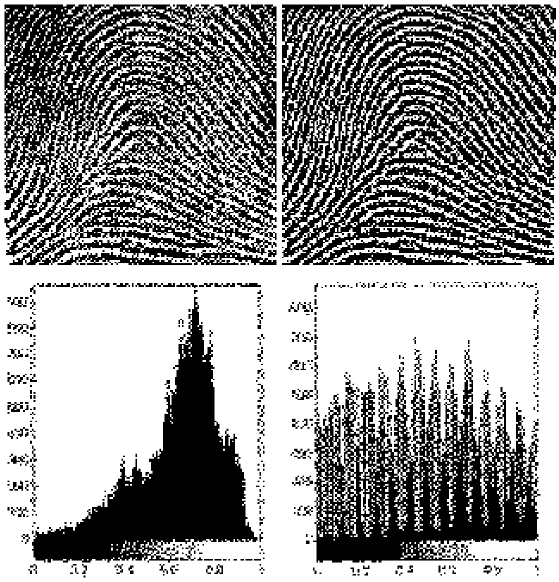


Figure 2.1 original image and its Histogram (left) and after equalization (right)

Thus Histogram equalization produces the contrast enhanced fingerprint image for the Multistage Median Filter (MMF) noise removal process.

2.2 MULTISTAGE MEDIAN FILTER:

Performs filtering of a video stream using the multistage implementation of the median filter. The same procedure as in Moving Average Filter is followed, with the difference that only one parameter is given for the 3D window size, as it can only be cubic.

Pixels in a low bit-rate encoded image are categorized into two or more categories. In one embodiment three pixel categories are used: 1) pixels belonging to quasi-constant (QC) regions where the pixel intensity values vary slowly 2) pixels belonging to textured regions which are characterized by many small edges and thin-line signals portions), and 3) pixels belonging to dominant-edge (DE) regions which are characterized by few sharp and dominant edges. In one embodiment dominant-edge pixels are categorized first, then quasi-constant and textural pixels are distinguished from the remaining pixels using the number of zero-crossings among the pixels and a threshold. Conventional spatial filters that are well suited for each pixel category type are then used to enhance each region of the image. In one embodiment, various combinations of spatial filters are used to enhance the image.

The median filter has been frequently used in image processing. Although it does a good job at suppressing noise, features such as thin lines are removed.

Let {x(.,.)} be a discrete two-dimensional sequence, and consider the set of elements inside a (2N+1)x(2N+1) square window W centered at the $(i,j)^{th}$ pixel.

Define the following four subsets of the window W:

$W_{0,1}(i,j) = \{x(i,j+k); -N \leq k \leq N\}$ (1)

$W_{1,1}(i,j) = \{x(i+k,j+k); -N \leq k \leq N\}$ (2)

$W_{1,0}(i,j) = \{x(i+k,j); -N \leq k \leq N\}$ (3)

$W_{1,-1}(i,j) = \{x(i+k,j-k); -N \leq k \leq N\}$ (4)

Suppose that $z_s(i,j)$ (s=1,2,3,4) are the median values of the elements in the four subsets, respectively, and

$Y_p(i,j)=\min[z_1(i,j), z_2(i,j), z_3(i,j), z_4(i,j)]$ (5)

$Y_q(i,j)=\max[z_1(i,j), z_2(i,j), z_3(i,j), z_4(i,j)]$ (6)

Then the output of the multistage median filter (MMF) is defined by

$Y_m(i,j)=\mathrm{med}[y_p(i,j), y_q(i,j), x(i,j)]$ (7)

One of the advantages of the MMF is its ability to preserve details of images. For example, the three pixel long bright line can be preserved with a 3x3 window. The fingerprint filtered by Multistage Median Filter is shown in Fig.3.

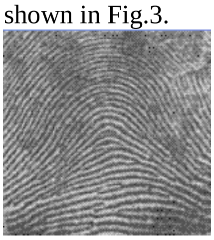


Fig.3. Filtered Image

2.3 BINARIZATION:

The operation that converts a grayscale image into binary image is known as binarization. Binarization refers to the process of reducing the bit depth of the grayscale image to just 1 bit per pixel. The straight forward approach for binarization relies on choosing a global threshold T. The binarized image I is obtained as follows.

$$I_{new}(n_1,n_2) = \begin{cases} 1 \ \ if \ \ I_{old}(n_1,n_2) \geq Local \ \ Mean \\ 0 \ \ otherwise \end{cases} \qquad (2\text{-}3)$$

This is a very well studied problem in the area of image processing and computer vision. There exists optimal approach to determine this threshold T based on the statistics of the gray scale distribution within the image. However, due to the non-stationary nature of the fingerprint, such algorithms are not suitable or are sub-optimal at best. The brightness of the image may vary across different regions of the fingerprint image. Therefore an adaptive binarization is often used for this purpose. In such techniques, the threshold T is determined locally considering the properties of the local neighborhood.

The local adaptive thresholding is applied to the directionally filtered image, which produces the final enhanced binary image. This involves calculating the average of the gray-level values within an image window at each pixel, and if the average is greater than the threshold, then the pixel value is set to a binary value of one; otherwise, it is set to zero. The gray-level image is converted to a binary image, as there are only two levels of interest, the foreground ridges and the background valleys.

The fingerprint images possess ridge flow patterns with slowly changes in directions. They may have various gray-level values due to non-uniformity of the ink intensity, non-uniform contrast with the sensors by users or changes in illumination and contrast during image acquisition process. Obviously, Global thresholding method fails to create good quality binary images for further feature extractions. The resultant image of the given fingerprint image is shown in Fig.4.

Fig.4. Binarized Fingerprint Image

We carried out the binarization process using an Adaptive threshold that separates the foreground from the background with non uniform illumination. In this approach, each pixel is successively examined and assigned white and black value. This is of particular importance, since the binarization step is very critical to the process of minutiae detection. Errors in this stage propagate into subsequent phases of feature extraction. Therefore, the binarization process has to be robust and resilient to the quality of input image.

2.4 THINNING

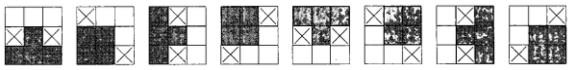
The final image enhancement step typically performed prior to minutiae extraction is thinning. Thinning is a morphological operation that successively erodes away the foreground pixels until they are one pixel wide. A standard thinning algorithm, Hit-or-Miss Transformation is employed, which performs the thinning operation using two sub iterations. Each sub iteration begins by examining the neighbourhood of each pixel in the binary image, and based on a particular set of pixel-deletion criteria, it checks whether the pixel can be deleted or not. These sub iteration continues until no more pixel can be deleted.

The thinning of a Binarized image is achieved by using the structuring elements{B} which is shown in Fig.5.

$$\{B\} = \{B^1, B^2, \ldots\ldots B^8\}$$

The process of thinning is done by the following equation,

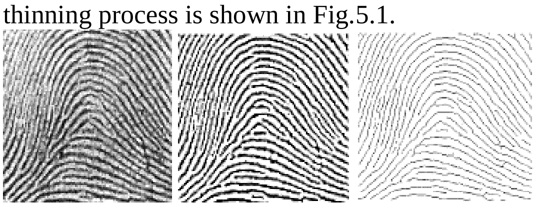
$$(\text{Binarized Image} ¤ B^1) ¤ B^2 \ldots ¤ B^8 \qquad (2.4)$$



B^1 B^2 ……………………………….. … B^8

Fig.5. Structure Elements

The application of the thinning algorithm to a fingerprint image preserves the connectivity of the ride structures while forming a skeleton version of the binary image. This skeleton image is then used in the subsequent extraction of minutiae. Automatically detected minutiae may be slightly perturbed from its original location because of the noise introduced during the binarizing and thinning processes. Hence we should apply the thinning process without affecting the minutiae locations. The resultant of thinning process is shown in Fig.5.1.



(a) Original image (b) Binary image (c) Thinned image

Fig.5.1. Fingerprint Image after Applying Binarization and Thinning

III. POSTPROCESSING:

The post processing stage of the proposed algorithm involves the detection of true minutiae, the ridge ending and bifurcation.

3.1 DETECTION OF TRUE MINUTIAE

The candidate minutiae are detected in a single scan of the thinned ridge map image using 3 x 3 windows. Each ridge pixel (value 1) is classified based on the number of 0 to 1 transitions meet when making full clockwise trip along its 8 neighborhood pixels. If there is only one such transition then the pixel is classified as a candidate ridge ending. If the number of transition is 3 then the pixel is classified as a candidate ridge bifurcation. In all other cases the pixel is not included into the candidate minutiae set.

The number of candidate minutiae detected as above is much larger than the number of genuine minutiae in the fingerprint image. Most of the candidate minutiae have no meaning corresponding to the fingerprint image, they being associated with different false minutiae structures. The post processing algorithm present in the following tests the validity of each candidate minutiae by analyzing the thinned ridge map image in W x W neighborhood of the minutiae.

3.2 ALGORITHM

For each candidate minutiae (ridge ending and ridge bifurcation):

1. Create and initialize with 0 am image L of size W x W. each pixel of L corresponds to a pixel of thinned image which is located in a W x W neighborhood centered in the candidate minutiae.

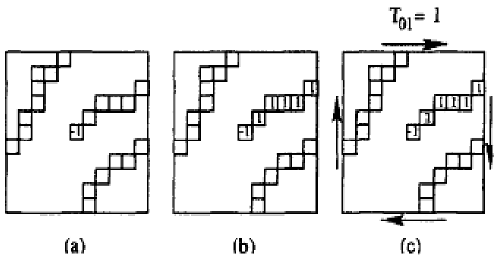


Fig.6. Example of Minutia validations.

2. Label with -1 the center pixel of L (Fig. 6(a), 7(a)). This is the pixel corresponding to the candidate minutiae point in the thinned ridge map image.
3. if the candidate minutiae is ridge ending then:
   a) Label with 1 all the pixel in L with correspond to the pixel connected with the candidate ridge ending in the thinned ridge map image(Fig.6(b)).
   b) Count the number of 0 to 1 transition (T_{01}) met when making full clock wise trip along the border of the L image (Fig.6(c)).
   c) If T_{01} =1, then validate the candidate minutiae as true ridge ending.

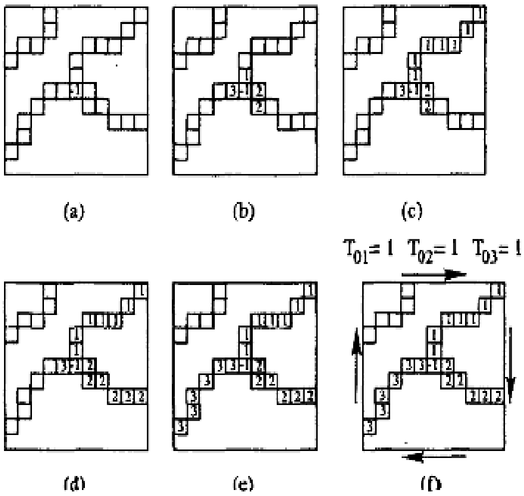
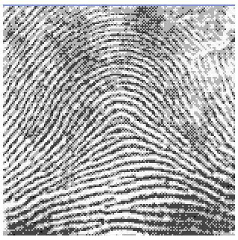


Fig.7. Changes in the L images after different steps of the algorithm.

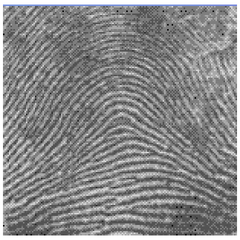
4. if the candidate minutiae is a ridge bifurcation then:
   d) Make a full clockwise trip along its 8 neighborhood pixels of the candidate ridge bifurcation, and label in L with 1,2 and r respectively the three connected components met during this trip(Fig. 7(b)).
   e) For l=1,2,3 (Fig. 7 (c),(d),(e), label with l all pixels in L which:
      i. Have the label 0;
      ii. Are connected with an l labeled pixels;
      iii. Correspond to 1 valued pixels in thinned ridge map;
   f) Count the number of 0 to 1, 0 to 2, 0 to 3 transitions met while making a full clockwise trip along the border of the L image. The above three numbers are denoted by T_{01}, T_{02} and T_{03} respectively as shown in (Fig.7(f)).
   g) If $T_{01}=1 \wedge T_{02}=1 \wedge T_{03}=1$, then validate the candidate minutiae as a ridge bifurcation.

The dimension W of the neighborhood analyzed around each candidate minutiae is chosen larger then two times the average distance between two neighborhood ridges.

IV. FINAL RESULS PREPROCESSING:



A.Histogram Equalized Image



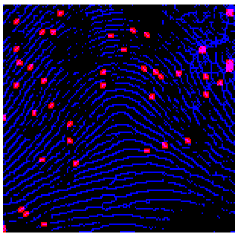
B. Multistage Median Filtered Image

C. Binarized Image

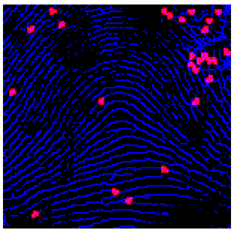
D.Thinned Image

Fig.8. Output of Preprocessing

POSTPROCESSING:



A.True Ridge End



B. True Ridge Bifurcation

Fig.9. Output of Post processing

V. CONCLUSION

The primary goal of Fingerprint Feature Extraction(FFE) is the enhancement of the fingerprint images using Multistage Median Filter and also extract true minutiae from the thinned fingerprint images. Firstly, this paper focused a series of techniques for fingerprint image enhancement to facilitate the extraction of minutiae. Experiments were then conducted using a combination of both good test images and poor fingerprint images in order to provide a well balance evolution on a more qualitative and accurate measure of the performance. Whereas poor images rely on qualitative measures of inspection, but can provide a more realistic evaluation as they provide a natural representation of fingerprint imperfection such as noise and corrupted elements.

The final results have shown that combined with an accurate estimation of the minutiae, the multistage median filter is able to effectively enhance the clarity of ridge structures while reducing noise. In contrast, for low quality images that exhibit high intensities of noise, the filter is highly effective in enhancing the image.

Overall, the results have shown that the implemented enhancement algorithm is a useful step to employ prior to minutiae extraction. Thus the proposed Fingerprint Feature Extraction (FFE) algorithm implements a set of reliable techniques for fingerprint image enhancement and minutiae extraction.

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