Fingerprint Recognition Using Minutiae Extraction Method

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***Abstract:* - Biometrics is one of the biggest tendencies in human identification. The fingerprint is the most widely used biometric. However considering the automatic fingerprint recognition a completely solved problem is a common mistake. The most popular and extensively used method is the minutiae-based method. This paper summarizes a simple procedure for pre-processing and extracting minutiae from digital fingerprint images.**

***Key-words:* - Fingerprint, Average Gradient, Ridge, Valley, Bifurcation, Ridge Ending, Minutiae.**

1. Introduction

Fingerprints are the graphical flow-like ridges present on human fingers. Finger ridge configurations do not change throughout the life of an individual except due to accidents such as bruises and cuts on the fingertips. This property makes fingerprints a very attractive biometric identifier. Fingerprint-based personal identification has been used for a very long time [1]. Owning to their distinctiveness and stability, fingerprints are the most widely used biometric features. Nowadays, most automatic fingerprint identification systems (AFIS) are based on matching minutiae, which are local ridge characteristics in the fingerprint pattern. The two most prominent minutiae types are ridge ending and ridge bifurcation. Based on the features that the matching algorithms use, fingerprint matching can be classified into image-based and graph-based matching.

Image-based matching [2] uses the entire gray scale fingerprint image as a template to match against input fingerprint images. The primary shortcoming of this method is that matching may be seriously affected by some factors such as contrast variation, image quality variation, and distortion, which are inherent properties of fingerprint images. The reason for such limitation lies in the fact that gray scale values of a fingerprint image are not stable features.

Graph-based matching [5], [7] represents the minutiae in the form of graphs. The high computational complexity of graph matching hinders its implementation. To reduce the computational complexity, matching the minutiae sets of template and input fingerprint images can be done with point pattern matching. Several point pattern matching algorithms have been proposed and commented in the literature [3], [4], [8], [10], [11].

Fingerprint system can be separated into two categories *Verification* and *Identification.* Verification system authenticates a person's identity by comparing the captured biometric characteristic with its own biometric template(s) pre-stored in the system.

It conducts one-to-one comparison to determine whether the identity claimed by the individual is true. A verification system either rejects or accepts the submitted claim of identity.

Identification system recognizes an individual by searching the entire template database for a match. It conducts one-to-many comparisons to establish the identity of the individual. In an identification system, the system establishes a subject's identity (or fails if the subject is not enrolled in the system database) without the subject having to claim an identity.

In order to implement a successful algorithm of this nature, it is necessary to understand the topology of a fingerprint. A fingerprint consists of many ridges and valleys that run next to each other, ridges are shown in black and valleys are shown in white.

The ridges bend in such ways as to form both local and global structures; either of which can be used to identify the fingerprint. The global level structures consist of many ridges that form arches, loops, whirls and other more detailed classifications, as shown in Figure 5. Global features shape a special pattern of ridge and valleys. On the other hand, the local level structures, called minutiae, are further classified as either endpoints or bifurcations. Minutiae are also given an associated position and direction, as shown in Figure 1 and in Figure 3.

Our procedure is mainly based on minutiae, as well as on global level structure for finding a reference point by which alignment of two template is to be accomplished.

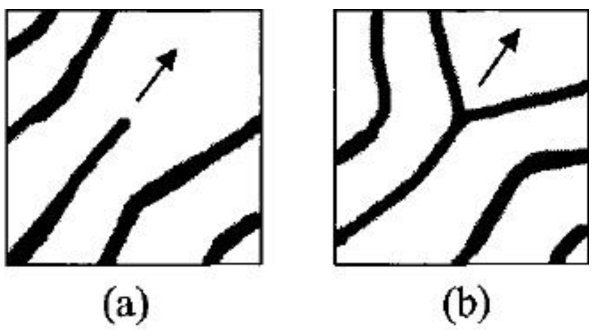


Figure **1:** Types of fingerprint minutiae and their respective directions.
(a) an endpoint, (b) a bifurcation.

In addition, scanned fingerprints are subject to distortions that must also be taken into account including rotation, translation, non-linear scaling and extraneous or missing minutiae between matching fingerprints. This creates difficulty in the matching phase because it causes the minutiae to differ between two identical fingerprints.
Figure 4 shows a fingerprint image with extracted minutiae.

2. Background

Most approaches to recognizing a fingerprint involve five basic stages: (i) acquisition, where the image is obtained from hardware or a file; (ii) pre-processing, which may include thinning, noise reduction, image enhancements and error correction; (iii) structural extraction, where global and local structures may be found; (iv) post-processing, where the structures are converted into a more useful format; (v) and then matching, where fingerprints are compared against a database. These stages are shown in Figure 2.

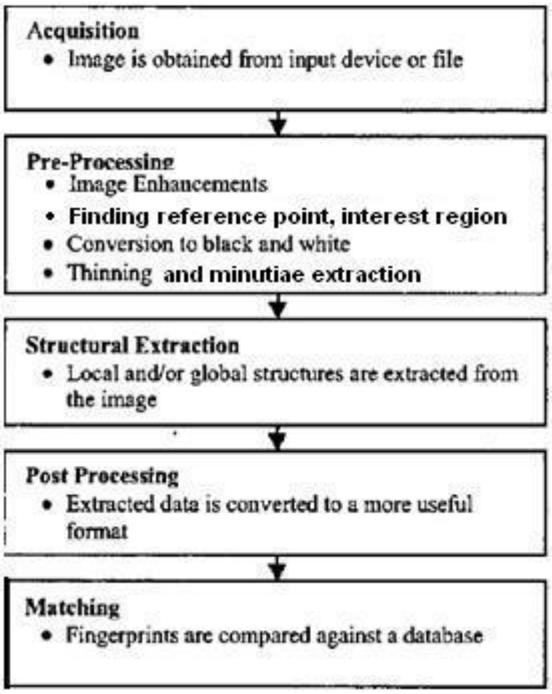
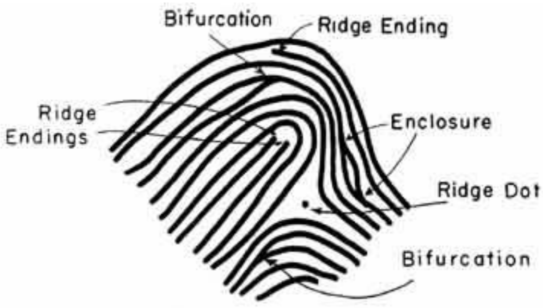
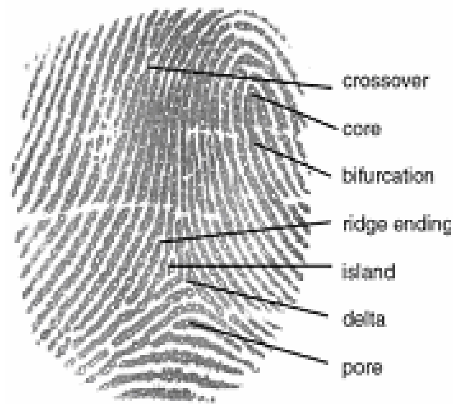


Figure 2: Stages of the fingerprint recognition process.

The method chosen for acquisition of a fingerprint image depends on many different factors, including the cost and reliability of an input device.



(a)



(b)

Figure 3: Fingerprint images showing Minutiae.

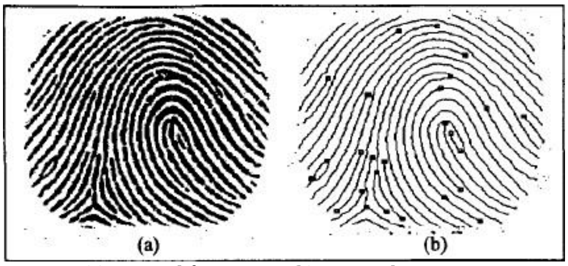


Figure 4: (a) Original fingerprint. (b) Detected minutiae.

Arch Tented Arch Left Loop Right Loop Whorl

Figure 5: Fingerprint Patterns.

3. Pre-processing

This is an essential part of fingerprint recognition. In this step the image is made ready for the actual matching. The input of this phase is the original fingerprint image and the final output of this step is the minutiae of that image.
Our proposed algorithm for pre-processing is as followed.

3.1. Fingerprint image enhancement

Three types of degradations affect the quality of the fingerprint image. The ridges get some gaps; parallel ridges connected due to noise and natural effect to the finger like cuts, wrinkles and injuries. The Fingerprint enhancement is anticipated to improve the contrast between ridges and valleys and reduce noises in the fingerprint images.

High quality fingerprint image is very important for fingerprint verification or identification to work properly. In real life, the quality of the fingerprint image is affected by noise like smudgy area created by over-inked area, breaks in ridges created by under-inked area, changing the positional characteristics of fingerprint features due to skin resilient in nature, dry skin leads to fragmented and low contrast ridges, wounds may cause ridge discontinuities and sweat on fingerprints also leads to smudge marks and connects parallel ridges.

3.2. Noise reduction

Noise is an unwanted perturbation to a wanted signal. Image noise is generally regarded as an undesirable by-product of image capture. Noise reduction is the process of removing noise from a picture (here it is fingerprint image).

3.3. Image normalization

The objective of this stage is to decrease the dynamic range of the gray scale between ridges and valleys of the image in order to facilitate the processing of the following stages.

3.4. Selection of the interest region

Since the image has background noise, the algorithm may generate minutiae outside the fingerprint area. So selection of the interest area is one important step.

This step is carried in few phases: (a) divide the image into blocks, (b) find the average gradient of each block, (c) find the position of the image where the average gradient of two successive blocks has the zero crossing and the maximum absolute value, (d) take the approximate middle point of these two particular blocks as the reference point, (e) crop out a suitable region around this reference point.

The elementary orientations in the image are given by the gradient vector $[Gx(x,y)\ Gy(x,y)]^T$, which is defined as:

$$\begin{bmatrix} Gx(x,y) \\ Gy(x,y) \end{bmatrix} = \mathrm{sign}(Gx)\boldsymbol{\nabla} I(x,y) = \mathrm{sign}(\partial I(x,y)/\partial x) \begin{bmatrix} (\partial I(x,y)/\partial x) \\ (\partial I(x,y)/\partial y) \end{bmatrix} \quad (1)$$

where I(x,y) represents the gray-scale image.

3.5. Binarization

In the pre-processing stage, the image is converted from greyscale to black and white. This is done by calculating the average background intensity and subtracting this value from the greyscale image. Next a greyscale threshold is calculated so pixels above this value become black, and the ones below become white.

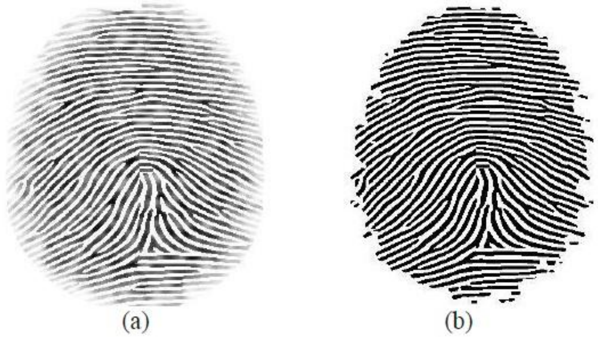


Figure 6: (a) Original Fingerprint, (b) Binarized Fingerprint.

3.6. Thinning

Next the ridges must be thinned to a width of one-pixel. In this step two consecutive fast parallel thinning algorithms are applied, in order to reduce to a single pixel the width of the ridges in the binary image. These operations are necessary to simplify the subsequent structural analysis of the image for the extraction of the fingerprint minutiae. The thinning must be performed without modifying the original ridge structure of the image. During this process, the algorithms cannot miscalculate beginnings, endings and or bifurcation of the ridges, neither ridges can be broken.

Figure 7 shows the thinned image of the binarized image.

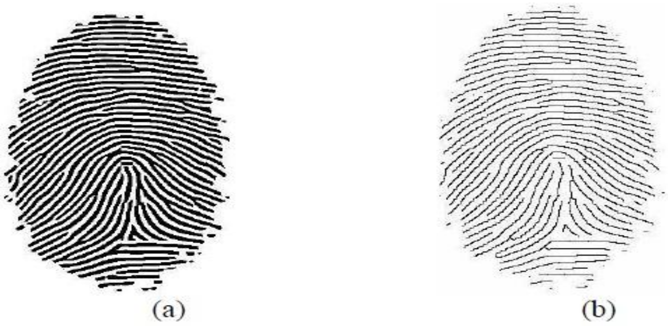


Figure 7: (a) Binarized Fingerprint , (b) Image after thinning.

3.7. Minutiae extraction

In the last stage, the minutiae from the thinned image are extracted, obtaining accordingly the fingerprint biometric pattern. This process involves the determination of: i) whether a pixel, belongs to a ridge or not and, ii) if so, whether it is a bifurcation, a beginning or an ending point, obtaining thus a group of candidate minutiae. Next, all points at the border of the interest region are removed.

3.8. Cancellation of improper minutiae

This is an important step of minutiae based fingerprint reorganization system. In this step, the improper minutia which are mainly result of spurious noise of input image, are cancelled.

4. Matching

Matching is a key operation in the current fingerprint identification system. One of the most important objectives of fingerprint systems is to achieve a high reliability in comparing the input pattern with respect to the database pattern. Reliably matching fingerprint images is an extremely difficult problem, mainly due to the large variability in different impressions of the same finger (i.e., large intra-class variations). The main factors responsible for the intra-class variations are: displacement, rotation, partial overlap, non-linear distortion, variable pressure, changing skin condition, noise, and feature extraction errors. Therefore, fingerprints from the same finger may sometimes look quite different whereas fingerprints from different fingers may appear quite similar.

The method employed in the research was minutiae based matching. A minutia matching essentially consists of finding the alignment between the template and the input minutiae sets, that results in the maximum number of minutiae pairings. In Minutiae based matching the similarity between the input and stored template are computed.

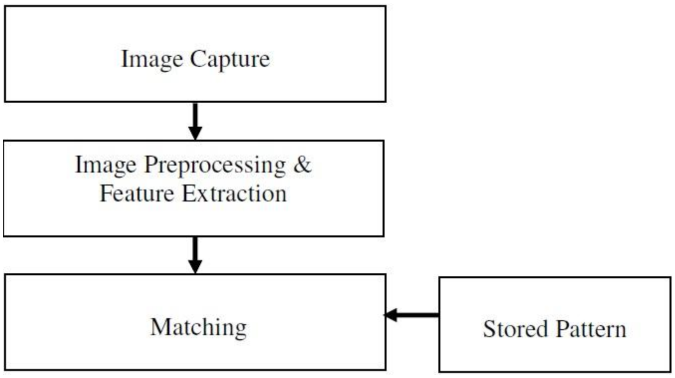


Figure 8*:* Fingerprint matching steps.

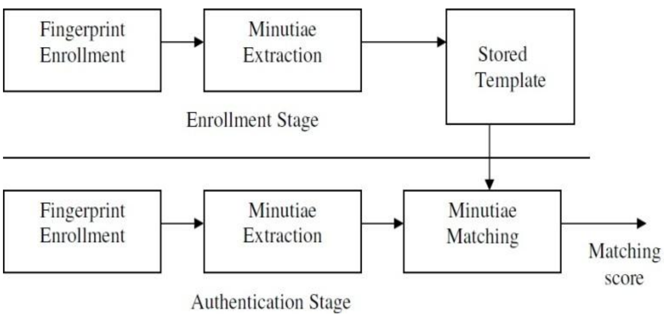


Figure 9*:* Fingerprint authentication steps.

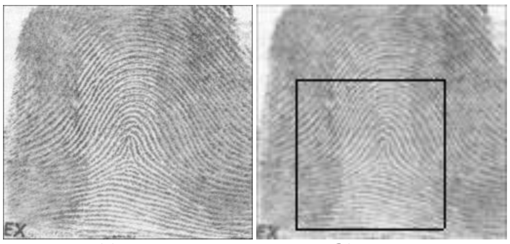
5. Experimental result

This Fingerprint Recognition System works for two types of matching.

One fingerprint image is fed into the system to check (a) whether it belongs to a particular database and if so then for which entry/entries of the database (Identification), or (b) if it confirms to be fingerprint of a particular person (Verification). This project further automatically adds new fingerprint to the database, if the fingerprint to be matched does not exist in the database previously.

Our proposed method is based on pixel to pixel matching. In this method the fingerprint image is being cropped with respect to a particular point (reference point) of the image; this cropped area is called the region of interest. In our system, the region of interest is taken as the 68 x 68 pixel block around the reference point.

We are using gradient calculation method to calculate the reference point. The reference point is being calculated by calculating the average gradient of 8 x 8 pixel block of the fingerprint image [6], [9]. For the maximum value of the average gradient of two successive blocks that has the zero crossing, the middle point of the successive blocks is taken as the reference point.



(a) (b)

Figure 10: Original picture and the calculated region to be cropped.

Currently we tested our algorithm on a small database (almost noise free dummy database of 100 entries). And the output we got confirms the desired output as we can check visually.

(a) (b) (c)

Figure 11: (a) original picture, (b) cropped region, (c) extracted minutiae

Figure 11 shows the original image, and the interest region and the minutiae extracted from the cropped region.

Here we have kept a threshold value for checking the number of minutiae matched. By changing the threshold value we get different rate of acceptance and rejection.

Figure 12(b) and Figure 12(c) are two distorted images obtained form Figure 12(a); (b) is accepted but (c) is not because of its high degradation.

(a) (b) (c)

Figure 12: (a) fingerprint to be matched with, (b) accepted little distorted image, (c) rejected more distorted image.

6. Discussion

There have been many algorithms developed for extraction of both local and global structures. Most algorithms found in the literature are somewhat difficult to implement and use a rather heuristic approach.

Here in our proposed method, we have used 8 x 8 pixel block for gradient calculation. And we have taken 68 x 68 pixel values around the reference point, as we used the method on dummy database, for larger database having larger fingerprint image sizes, the pixel values can be suitably changed.

For noisy database, we have seen that the 4 x 4 pixel block for gradient calculation is giving us a better result.

It is also seen that this gradient approach is not suitable for all kinds of fingerprints, and further attributes are also required in order to accomplish the matching.

In our future work, we are trying to solve this shortcoming.

7. Future Scope

In this paper, minutiae extraction based fingerprint detection was applied with gradient detection as a step, to find the reference point.

The singular point detection method can be applied as a step to cluster the fingerprint images into five major groups (i.e. arch, tented-arch, left loop, right loop, whorl), and then this minutiae extraction based method can be applied on the clusters to achieve a hierarchical fingerprint detection algorithm. We are trying to incorporate this approach in future.

Clustering the fingerprint images in five major groups is quite easy if it is done manually by visual checking, but implementing an automated system for this is quite a hard job.

We are also investigating different soft computing approaches for calculating the reference point, as well as minutiae, for better result.

This method is not yet generalised, finer approach will be taken in future. If the image is not noisy, it calculates the reference point to be the singular point.

In future we have to search for and apply position invariant features.

Also our method is yet to be tested on large database.

8. Conclusions

The reliability of any automatic fingerprint recognition system strongly relies on the precision obtained in the minutiae extraction process.

The minutiae based matching is highly sensible, as, if the finger is moved even a little bit that gives us a different set of minutiae.

9. Reference

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