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# Analysis of Fingerprint Minutiae Extraction and Matching Algorithm

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***Abstract* - Biometrics is one of the most proficient authentication techniques and provides a method to validate a person to protect from any misleading actions. It can be used for personal authentication using physiological and behavioral features which are presumed to be characteristic for each individual. Due to its security-associated applications currently biometrics is the subject of intense research by academic institutions and private. However, each trait has its specific challenges and particular issues. Though various biometric techniques have certain concerns fingerprint is accepted by many researchers because fingerprint recognition systems has received a great deal of its easiness and believed to give effective solution to person authentication. It provides a powerful tool for access control, security and for real-world applications. Fingerprints are developing as the most common and trusted biometric for individual identification. The major objective of this study is to review the wide research that has been done on automatic fingerprint identification system based on minutiae extraction and matching algorithms. Minutiae features have most of a fingerprint's individuality, and furthermost important fingerprint feature for authentication systems. Minutiae extraction, matching algorithms, and identification/verification performance are discussed in detail with open problems and future directions acknowledged.**

***Keywords*— biometrics, fingerprint, image enhancement, minutiae extraction, matching algorithm**

## I. Introduction

Biometrics has been in the development for several years and with the recent advancements in technology has been made of some biometrics affordable and more reliable. Biometrics refers to the automatic recognition of individuals based on their characteristics. Biometric modalities can be divided into three main categories: Psychological, behavioral and chemical. Physiological are based on the nature of the body. A fingerprint is one of the physiological nature traits that have been used more than 100 years. Other physiological traits are Face, Retina, Vein pattern, Palm print, Hand geometry, DNA, Facial thermo grams, Fingernail bed, Brainwave pattern, Biodynamic signature , Oto acoustic emissions , Ear shape , Skin spectrograph etc. Behavioral are associated to the behavior of a person. The signature is a broadly used form of identification and verification. Other behavior approaches are handwritten signature, Keystroke dynamics, Handgrip dynamics, Voice, Lips dynamics, Mouse dynamics, etc. Other biometrics traits have been researched and developed are based on a individuals' way of walking, also known as their "gait" Chemical biometrics is still a emerging field and involves evaluating chemical cues such as body odor and the chemical composition of human sweat. .There is several biometric characteristics on persons that can be used for identification / verification purposes. These biometric characteristics posses' features which can be extracted for the determination of automated recognition of individuals.

Following the introduction, the rest of the paper is organized as follows. Section II describes on existing methods in the field of fingerprint image enhancement, feature extraction and matching. Section III gives a fingerprint image enhancement algorithm based on Gabor filtering. Section IV presents a novel feature extraction algorithm based on crossing number (CN) concept. Section V describes an alignment-based minutiae matching algorithm and section VI is conclusion.

## II. RELATED WORK

### A. Fingerprint image enhancement

Fingerprint enhancement techniques is one of the most widely cited method The major task of fingerprint enhancement is needed to reconstruct the real fingerprint pattern as true to unique as possible. Hong et al. [1] suggested an algorithm using Gabor band pass filters tuned to the equivalent orientation and ridge frequency to remove unwanted noise while preserving the exact ridge-valley structures. Sherlock et al. [2] named directional Fourier filtering. The prior approach was a spatial domain procedure that involves spatial convolution of the image with filters, which can be computationally great expensive.

### B. Minutiae extraction and post-processing

Crossing number (CN) [3] is a most commonly employed method of minutiae extraction this technique involves the use

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of the skeleton image. Jain et al [4] and Ratha et al. [5] have also proposed minutiae extraction using the skeleton image.

C. Fingerprint image post-processing

Image post-processing approaches are based on a series of structural rules used to remove spurious minutiae. Ratha et al. [5] offered which performs the validation of minutiae based on a set of heuristic rules. For instance, a ridge ending point that is joined to a bifurcation point, and is less than a certain threshold distance is eliminated. A novel approach to validation of minutiae is post-processing algorithm offered by Tico and Kuosmanen [6].

D. Fingerprint matching

Basically Fingerprint matching techniques is broadly categorized in three classes [7] namely, correlation-based matching, minutiae-based matching and ridge feature-based matching. The correlation-based matching approach is a straight method is used to compare the corresponding pixel passion of the fingerprint image in many of rotating and shifting. In minutiae-based method, [8] the fingerprint information called minutiae. The minutiae feature extracted from the fingerprint image and used some matching process. In literature [9] have been proposed a number of point pattern matching algorithms because a general point matching problem is fundamentally intractable, features related with each point and their spatial properties such as the relative spaces between points are often used in this algorithms to decrease the exponential number of search paths.

## III. METHODOLOGY FOR FINGERPRINT ENHANCEMENT

The image enhancement techniques to reduce the noise and enhance the characteristics of ridges against valleys. In this chapter discussion on the methodology of a fingerprint image enhancement, minutiae extraction, matching algorithm. Fingerprint image enhancement algorithm Fingerprint image enhancement algorithm consists of the following phases. segmentation, normalization, orientation estimation, Ridge frequency estimation, Gabor filtering. binarization thinning.

A. Segmentation

The initial process of image enhancement algorithm is fingerprint segmentation, in the segmentation process the foreground region is separating from background region. The acquire fingerprint image is separated into blocks then the grey-scale variance is calculated for all block in the image. If the variance value is less than the fixed global threshold [10] value then the block is considered as background region. Further the remaining parts to be considering foreground region .the block size of grey-level variance is $WxW$ is demarcated as below.

$$V(k) = \frac{1}{w^2}\sum_{i=0}^{w-1}\sum_{j=0}^{w-1}(I(i,j) - M(k))^2$$

- $V(k)$ is the variance for given block $k$
- $I(i, j)$ is the grey-level value at pixel $(i, j)$,
- $M(k)$ is the mean grey-level value for the block $k$.

B. Normalization

. The normalization process standardizes the image intensity values and adjusting the range of grey-level values. So that it lies inside a preferred range of values.

$$N(i,j) = \begin{cases} M_0 + \sqrt{\frac{V_0(I(i,j) - M)^2}{V}} & ,if\ I(i,j) > M \\ M_0 - \sqrt{\frac{V_0(I(i,j) - M)^2}{V}} & ,Otherwise \end{cases}$$

- Here, $N(i, j)$ represent the normalized grey-level value at pixel $(i, j)$,
- Where $M$ and $V$ are the estimated mean and variance of $I(i, j)$,
- $M0$ and $V0$ are the preferred mean and variance values,

In the Normalization process does not change the original ridge structures in a fingerprint; it is performed to homogenize the dynamic levels of difference in grey-level values, which simplifies the processing of subsequent image enhancement phases.

C. Orientation estimation

In this method the fingerprint image defines the local orientation of the ridges contained in the fingerprint. Hong et. al. [1] proposed least mean square estimation method. This method used to calculate the orientation image. Though, instead of estimating the orientation using block-wise,

Rule for orientation estimation

1. Given image is separated into $w \times w$ pixel blocks (where $w$ is an odd number.)
2. Calculate the ridge lengths, $Li$, $i = 0 \ldots N$, for each block, where the direction

Of Li is set to $i\times(180/N)$. Let $Lmin$ be the minimum between $Li$ and $Lmax$ be the maximum. Plot the ridge length and histogram direction diagram.

3. Detect whether

(i) $Lmin$ and $Lmax$ are sole from 0 degree to 180 degrees,

(ii) Monotonically increase the ridge lengths from $Lmin$ to $Lmin+90$,

(iii) Monotonically decrease the ridge lengths from $Lmax$ to $Lmax+90$,

(iv) The direction between $Lmin$ and $Lmax$ is 90 degrees.

If yes, the block marked as a *certain* block and let the orientation is *max* degrees. Else, the orientation of the remaining block is considered as *uncertain*.

D. Ridge frequency estimation

The frequency image characterizes the local frequency of the ridges in a given fingerprint. In the frequency estimation process can be divided in to two steps. the first step the image divided in to block of size $W \times W$. the second step is to project the grey-level values of each pixels located inside

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of all the block along a direction orthogonal towards the local ridge orientation. This projection forms a nearly sinusoidal wave with the local minimum points corresponding to ridges in the fingerprint. The ridge spacing S(*i*, *j*) is then calculated by including the median number of pixels among consecutive minima points in the projected waveform.

$$F(i,j) = \frac{1}{S(i,j)}$$

Therefore, the ridge frequency *F* (*i*, *j*) for a block centred at pixel (*i*, *j*) is defined.

E. Gabor filter

A local ridge frequency estimation construction by Gabor filters. The even-symmetric Gabor filter used to construct and determine the ridge orientation and ridge frequency. A 2D Gabor filter contains of a sinusoidal plane wave of a specific orientation and frequency, Further Modulated by a Gaussian envelope [1]. Gabor filters are employed as they have frequency-selective, orientation-selective properties. These properties allow the filter to be set to give maximal response to ridges at an exact orientation and frequency in the fingerprint image. Therefore, a properly tuned Gabor filter can be used to successfully preserve the ridge structures while decreasing noise. The Gabor function is the real part of even-symmetric Gabor filter. This is given by a cosine wave modified by a Gaussian [1] an even symmetric

$$G(x,y;\theta,f) = exp\left\{-\frac{1}{2}\left[\frac{x_\theta^2}{\sigma_x^2} + \frac{y_\theta^2}{\sigma_y^2}\right]\right\}cos(2fx_\theta)$$

Gabor filter in the spatial domain is demarcated as:

$$x_\theta = xcos\theta + sin\theta$$

$$y_\theta = -xsin\theta + ycos\theta$$

- Wherever θ is considered as the orientation of Gabor filter.
- *f* stands for frequency of the cosine wave.
- σ *x* and σ *y* are the standard deviations of the Gaussian envelope along the *x* and *y* axes, respectively.
- *x*θ and *y*θ describe the *x* and *y* axes of the filter coordinate frame.

F. Binarization

Binarization is used to translate a grey-level image into a binary image. This method increases the difference among the ridges and valleys in a fingerprint image, where there are only two levels of interest, the black pixels that represent ridges, and the white pixels that represent valleys. After the image enhancement during the binarization process examining the grey- level value of each pixel and if the examined grey-level value is greater than the global threshold, then that the pixel value is set to a binary value '1', Then, it is set to '0'. The effect is a binary image holding two levels of information, such as the foreground ridges and the background valleys. The bellow given equation is used to acquire binary image.

$$BW(x,y) = \begin{cases} 1, & if\ I(x,y) \geq Tp \\ 0, & Otherwise \end{cases}$$

Here, I (x, y) denote the intensity value of enhanced grayscale image at pixel position (x, y). Let Tp be the threshold value. Now fingerprint images Tp denotes the differentiating intensity among the background pixels and ridge pixels. BW(x, y) characterize the binary image gained by the equation.

I. Thinning

Thinning is the final process of image enhancement it performed prior to minutiae extraction. Thinning is a morphological process that continually erodes away the foreground pixels till they are one pixel wide. Standard thinning algorithm use two sub iteration. This procedure is available in MATLAB through the `thin' operation below the bwmorph() function. Beginning of each iteration examining the neighborhood of each pixel in the binary image, and based on a specific set of pixel-deletion criteria, it checks whether the pixel can exist deleted or not. Those sub iteration end until no more pixels can be deleted.

## IV. MINUTIAE EXTRACTION & POSTPROCESSING

After a fingerprint image has been enhanced, the subsequent step is to extract minutiae from enhanced image. In the post-processing stage is performed to remove false minutiae. The minutiae extraction technique based on the broadly employed Crossing Number method as demarcated.

A. Minutiae Extraction using crossing number (CN)

The Crossing Number (CN) technique is used to achieve minutiae extraction. This technique extracts the ridge endings and ridge bifurcations from the skeleton image through examining the local neighborhood of all ridge pixels using a 3×3 window. The CN for a ridge pixel *P* is given as.

$$CN = 0.5\sum_{i=1}^{8} |P_i - P_{i+1}|, P_9 = P_1$$

| | | |
|---|---|---|
| $P_4$ | $P_3$ | $P_2$ |
| $P_5$ | P | $P_1$ |
| $P_6$ | $P_7$ | $P_8$ |

Fig.1. 8- neighbor pixels

Where *Pi* is the pixel value in the neighborhood of *P*. For a pixel *P*, its eight- neighboring pixels are scanned in an anti-clockwise way. Shown in fig.1.After the CN for a ridge pixel has been calculated, the pixel can then be categorized allowing to the property of its CN value. Using the properties

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of the CN such as isolation point, ridge endpoint, bifurcation point, the ridge pixel can categorized as a ridge ending, bifurcation or non -minutiae point. For example, a ridge pixel with a CN of '1' matches to a ridge ending, and a CN of '3' matches to a bifurcation.

A. Fingerprint Image Post-processing

Tico and kuosmanen[8] proposed minutiae validation algorithm is used to eliminate false minutiae ,The initial process of this algorithm is to generate an image *M* of size *W* × *W*, where *M* relates to the *W* × *W* neighborhood cantered on the applicant minutiae point in the skeleton image. The central pixel of *M* relates to the minutiae point in the skeleton image, and so this pixel is measured with a value is one. The rest of the pixels in *M* are initialized to values of zero. Further the subsequent stages of this algorithm depend on whether the candidate minutiae point is a ridge ending or a ridge bifurcation.

1. Algorithm step for a detecting candidate ridge ending point:
Step1: label the pixels value is 1 in *M*, which are eight-connected with the ridge ending point.
Step 2: To count in a clockwise direction, the number of zero to one transitions (T01*)* along the border of image *M*. If T01 = 1, Then the candidate minutiae point is confirmed as a true ridge ending.

2. Determining for a candidate bifurcation point
**Step1:** Examine the eight-neighboring pixels surrounding the bifurcation point in a clockwise direction. For three pixels that are linked with the bifurcation point, marker them by the values of 1, 2, then 3, correspondingly.
**Step2:** label the rest of the ridge pixels that are linked to these three joined pixels. This labelling is related to the ridge ending method, though, instead of labelling a sole ridge branch, three ridge branches are currently labelled. Let *l* = 1, 2 and 3 represent the label for every ridge branch. For each *l*, label with *l* all the ridge pixels labelled with0, and are linked to an *l* labelled pixel.
**Step3:** To count in a clockwise direction, the initial transitions from 0 to 1 (T 01*)*, second 0 to 2 (T02*)*, and third 0 to 3 (T03*)* along the border of image *M*. If T01 = 1 ^*T* 02 = 1 ^*T* 03= 1, then the candidate minutiae point is validated as a true bifurcation.

## V. ALIGNED POINT PATTERN MINUTIAE MATCHING

An alignment-based matching algorithm is an efficient in discrimination, and fast. Minutiae matching algorithm decomposes into two phases like alignment and matching phases. In the alignment-based matching algorithm process has two identical point patterns, those points are exactly aligned with each other, and each pair of agreeing points is completely coincident. In such a situation, a point pattern matching can be just achieved by calculating the number of overlapping pairs. It is impossible to exactly recover the point position of each input minutia with respect to its corresponding minutia in the template. This method does not provide a satisfactory performance in practice. So the adaptive elastic matching algorithm by the capability to compensate the minutiae localization errors and nonlinear deformations. Let *M* denotes the minutiae in the template image and *N* denote the set of minutiae in the input image.

$$P = ((x_1^P, y_1^P, \theta_1^P)^T, \ldots\ldots\ldots, (x_M^P, y_M^P, \theta_M^P)^T)$$

$$Q = ((x_1^Q, y_1^Q, \theta_1^Q)^T, \ldots\ldots\ldots, (x_N^Q, y_N^Q, \theta_N^Q)^T)$$

Algorithm step for point pattern matching
**Step1**: Each minutiae point to translate the polar coordinate system with respect to the equivalent reference minutiae on which the alignment is performed.
**1**. Here $(x_i^*, y_i^*, \theta_i^*)$ are the coordinates of minutiae,
**2.** $(x^r, y^r, \theta^r)^T$ *is* the coordinates of the reference minutiae,
**3.** $(r_i, e_i, \theta_i)^T$ is the representation of the minutiae in polar coordinate system (*ri* denotes the radial distance, *ei denotes* the radial angle, and *qi* denotes the orientation of the minutiae by respect to the reference minutiae).

$$\begin{pmatrix} r_i \\ e_i \\ \theta_i \end{pmatrix} = \begin{pmatrix} \sqrt{(x_i^* - x^r)^2 + (y_i^* - y^r)^2} \\ \tan^{-1}\left(\frac{y_i^* - y^r}{x_i^* - x^r}\right) \\ \theta_i^* - \theta^r \end{pmatrix}$$

**Step2:** The above template and the input minutiae in the polar coordinate system as symbolic representation by concatenating each minutiae in the increasing order of radial angles as:

$$P_P = ((r_1^P, e_1^P, \theta_1^P)^T, \ldots\ldots\ldots, (r_M^P, e_M^P, \theta_M^P)^T)$$

$$Q_P = ((r_1^Q, e_1^Q, \theta_1^Q)^T, \ldots\ldots\ldots, (r_N^Q, e_N^Q, \theta_N^Q)^T)$$

Here $(r_*^P, e_*^P, \theta_*^P)^T$ **and** $(r_*^Q, e_*^Q, \theta_*^Q)^T$ represent the corresponding radial angle, and radius, normalized minutiae orientation with respect to the reference minutia, respectively
**Step3:** Match the resulting strings *Pp* and *Qp* with a dynamic programming algorithm [1] to find the edit distance between *Pp* and *Qp* which is described below.
**Step4:** Use the edit distance among *Pp* and *Qp* to establish the correspondence of the minutiae among *Pp and Qp*. The matching score, *Mpq*, is then computed according to given bellow.

$$M_{PQ} = \frac{100 Npair}{\max\{M, N\}}$$

Where *Npair* is the number of the minutiae. Which decrease in the bounding boxes of template minutiae. The maximum and minimum values of the matching score are 100 and 1, correspondingly. The former value indicates a perfect match, while the later value indicates no match at all.

## VI. CONCLUSIONS

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This paper demonstrated on the enhancement, extraction and matching algorithm for fingerprint image recognition. Fingerprint image enhancement was studied using Gabor filter approach. It's working principle based on the pixel-wise comparison resulting improved image quality. Fingerprint minutiae extraction algorithm used Crossing Number method to extract the ridge ending and bifurcation through local eight-neighborhood pixels. An alignment-based matching algorithm follows the point pattern matching method and it was found to be efficient and fast. Input minutiae and template minutiae are transformed to polygons in the polar coordinate structure and an elastic string matching algorithm was used to match the resultant polygons. The major outcome of the proposed work compared to the existing work is reduction in False Rejection Rate (FRR) and False Acceptance Rate (FAR) and performances of the Automatic Fingerprint Identification System (AFIS) is expected to be increased.

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