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Fingerprint Matching Using Minutiae Feature

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Abstract- Fingerprints have been used in identification of individuals for many years because of the famous fact that each finger has a unique pattern. Fingerprint is a pattern of ridges on a finger. Fingerprint matching is the process used to determine whether two sets of fingerprint detail come from the same finger. There exist multiple algorithms that do fingerprint matching in many different ways. Some methods involve matching minutiae points between the two images, while others look for similarities in the bigger structure of the fingerprint. This paper involves comparison between fingerprint matching based on minutiae matching method and analysis using performance parameter False Acceptance Rate and False Rejection Rate.

Index Terms- **Fingerprint, False Acceptance Rate, False Rejection Rate, Minutiae, Ridge.**

I. INTRODUCTION

A fingerprint is the pattern of ridges that appear on the surface of the fingertip. It is perhaps the most popular and reliable biometric characteristic used for human authentication. Fingerprint-based authentication systems have been widely adopted in many applications where high security levels are a need.

A fingerprint matching is an important technique for personal identification, the main reason for this is that every person is believed to have distinct fingerprints. Presently, several organizations are using fingerprints for not only criminal investigation but also to access control of restricted areas, border control, driving license applicants, liquor licenses, identification cards, smart cards, cellular phones, teller machines, verification of firearm purchasers, passports and visas. Fingerprints are one of the most popular biometrics techniques in both of verification and identification modes. In the verification mode, automatic fingerprints identification systems (AFIS) either accepts or rejects an individual identity. In the identification mode, AFIS recognizes an individual without a claimed identity.[1]

Minutiae based methods involves to extract minutiae like terminations and bifurcations from the fingerprint images, and then compares this data to the previously stored template data sets. Generally, minutiae based methods require a significant amount of preprocessing to produce accurate results. In correlation based techniques two fingerprint images are superimposed and the correlation between corresponding pixels is computed for different alignments The direct application of it rarely leads to acceptable results, mainly due to the following problems: (a) Non-linear distortion makes impressions of the same finger significantly different in terms of global structure. (b) A direct application of it is computationally very expensive. [5]

In Non-minutiae feature based techniques some other features of the fingerprint ridge pattern (e.g., local orientation and frequency, ridge shape, texture information) may be extracted more reliably than minutiae. Since minutiae-based methods require an image of good quality, ridge features offer an alternative for poor images.

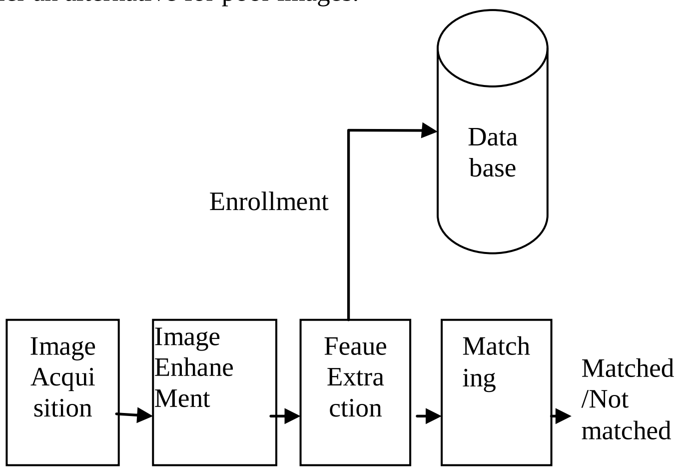

Fig 1: Block diagram of fingerprint recognition

II. IMAGE ACQUISITION STAGE

From the variety of sensors, like Optical sensors, Solid state sensors, one of the sensors can be used for image Acquisition. Image sensors take the impression of finger as input to fingerprint recognition system.

III. IMAGE ENHANCEMENT STAGE

Fingerprint Image enhancement is to make the image clearer for easy further operations. Since the fingerprint images acquired from sensors or other media are not assured with perfect quality, enhancement methods, for increasing the contrast between ridges and furrows and for connecting the false broken points of ridges due to insufficient amount of ink, are very useful to keep a higher accuracy to fingerprint recognition. Histogram Equalization and Fourier Transform can be used for Image enhancement stage.

A. Normalization

Normalization is used to standardize the intensity values in an image by adjusting the range of grey-level values so that it lies within a desired range of values. Let I(x,y) represent the grey-level value at pixel (x,y), and I'(x,y) represent the normalized grey-level value at pixel (x,y).[7]

$$I'[x,y] = m_0 + \left\{(I[x,y]-m)^2\left(\frac{v_0}{v}\right)\right\}^{\frac{1}{2}} if I[x,y] > m$$

$$I'[x,y] = m_0 - \left\{(I[x,y]-m)^2\left(\frac{v_0}{v}\right)\right\}^{\frac{1}{2}} otherwise$$

(1)

B. Histogram Equalization

Histogram equalization expand the pixel value distribution of an image so as to increase the perceptional information. The original histogram of a fingerprint image has more

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number of pixels having particular intensity and lower number of pixels of other intensity. The histogram after the histogram equalization occupies all the range.

C. Fast Fourier Transform

FFT is interesting technique that is able to perform a sort of contextual filtering without explicitly computing local ridge orientation and frequency. FFT can be implemented locally proposed by Watson, Candela, and Grother and Willis and Myers.[2]

D. Fingerprint Image Binarization

Fingerprint Image Binarization is to transform the 8-bit Gray fingerprint image to a 1-bit image with 0-value for ridges and 1-value for furrows. A locally adaptive binarization method is performed to binarize the fingerprint image. Such a named method comes from the mechanism of a transforming a pixel value to 1 if the value is larger than the mean intensity value of the current block (16x16) to which the pixel belongs and transforming a pixel value to 0 if the value is smaller than the mean intensity value of the current block to which the pixel belongs.

E. Local ridge orientation

The local ridge orientation at a pixel [x,y] is the angle θx,y that the fingerprint ridges, crossing through an arbitrary small neighborhood centered at [x,y] form with the horizontal axis. The simplest and most natural approach for extracting local ridge orientation is based on computation of gradients in the fingerprint image. The gradient g(x,y) at point [x,y] of image, is a two dimensional vector [gx(x, y),gy(x, y)], where gx and gy components are the derivatives of image at [x, y] with respect to the x and y directions, respectively.

Estimate the ridge orientation for each block of the fingerprint image with WxW in size.[5]

$$tg2ß = \frac{2\,\Sigma\Sigma(g_x * g_y)}{\Sigma\Sigma\,(g_x^2 - g_y^2)} \quad (2)$$

F. Fingerprint Image Segmentation

Maio and Maltoni suggest to find the average magnitude of gradient. Maio and Maltoni discriminated foreground and background by using the average magnitude of the gradient in each image block (i.e., contrast); in fact, because the fingerprint area is rich in edges due to the ridge/valley alternation, the gradient response is high in the fingerprint area and small in the background. After finished with the estimation of each block orientation, those blocks without significant information on ridges and furrows are discarded based on the following formulas:[3][6]

$$E = \frac{\{2\,\Sigma\Sigma(g_x * g_y) + \Sigma\Sigma\,(g_x^2 - g_y^2)\}}{W * W * \Sigma\Sigma(g_x^2 + g_y^2)} \quad (3)$$

For each block, if its certainty level E is below a threshold, then the block is regarded as a background block.

G. Thinning

Thinning is the process of reducing the thickness of each line of patterns to just a single pixel width. No further removal of pixels should be possible after completion of thinning process. Thinning is a morphological operation that successively erodes away the foreground pixels until they are one pixel wide. A standard thinning algorithm, which performs the thinning operation using two sub iterations. This algorithm is accessible in MATLAB via the `thin' operation under the bwmorph function. The application of the thinning algorithm to a fingerprint image preserves the connectivity of the ridge structures while forming a skeletonised version of the binary image. This skeleton image is then used in the subsequent extraction of minutiae.

IV. FEATURE EXTRACTION STAGE

A. Minutia Marking

The most commonly employed method of minutiae extraction is the Crossing Number (CN) concept. This method involves the use of the skeleton image where the ridge flow pattern is eight-connected. The minutiae are extracted by scanning the local neighborhood of each ridge pixel in the image using a 3×3 window. The CN value is then computed, which is defined as half the sum of the differences between pairs of adjacent pixels in the eight-neighborhood. [5]

$$C_n(P) = \left(\frac{1}{2}\right) \sum_{i=1}^{8} |P_i - P_{i+1}| \quad (4)$$

B. False Minutia Removal

False ridge breaks due to insufficient amount of ink and ridge cross-connections due to over inking are not totally eliminated. Hence, after the minutiae are extracted, it is necessary to employ a post processing stage in order to validate the minutiae. Following procedure is used in removing false minutia are: 1) If the distance between one bifurcation and one termination is less than D and the two minutia are in the same ridge. Remove both of them. Where D is the average inter-ridge width representing the average distance between two parallel neighboring ridges. 2) If the distance between two bifurcations is less than D and they are in the same ridge, remove the two bifurcations. 3) If two terminations are within a distance D and their directions are coincident with a small angle variation. And they suffice the condition that no any other termination is located between the two terminations. Then the two terminations are regarded as false minutia derived from a broken ridge and are removed.

V. MATCHING STAGE

The matching stage takes a feature set and enrollment template as input and computes the similarity between them in terms of a matching score. If the matching score is higher than the threshold, then the decision is matched and the person is recognized as genuine.

An alignment-based match algorithm includes two consecutive stages: one is alignment stage and the second is match stage[6]

A. Alignment stage

Let I1 & I2 be the two minutiae sets given by,

I1 $=\{m_1, m_2 \ldots m_M\}$ where $m_i = \{x_i, y_i, ø_i\}$

I2$=\{m_1', m_2' \ldots m_M'\}$ where $m_i' = \{x_i', y_i', ø_i'\}$

Now choose one minutia from each set to find the ridge correlation factor between them. So the similarity of correlating the two ridges is derived from:

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$$S = \sqrt{\frac{\sum_{i=0}^{m} x_i X_i}{\sum_{i=0}^{m} x_i^2 X_i^2}} \quad (5)$$

Where ($x_{i...}x_n$) and ($X_{i...}X_N$) are the set of minutia for each fingerprint image respectively. And m is minimal one of the n and N value. If the similarity score is larger than 0.8, then go to next step , otherwise continue to match the next pair of ridges.

The approach is to transform each set according to its own reference minutia and then do match in a unified x-y coordinate. Let M(x,y,θ) be reference minutia found from above step (say from I1). For each fingerprint, translate and rotate all other minutia with respect to the reference minutia according to hough transform.

B. Matching

According to the match algorithm minutia mi in I1' and a minutia mj in I2' are considered "matching," if the spatial distance (sd) between them is smaller than a given tolerance r0 and the direction difference (dd) between them is smaller than an angular tolerance θ0.

$$sd = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \leq r_0$$

$$dd = \min(|\theta_i - \theta_j|, 360 - |\theta_i - \theta_j|) \leq \theta_0 \quad (6)$$

Let mm(.) be an indicator function that returns 1 in the case where the minutiae mi and mj match according to above equations.

$$mm(m_i, m_j) = \begin{cases} 1, if\ sd(m_i, m_j) \leq r_0\ and\ dd(m_i, m_j) \leq \theta_0 \\ 0,\ otherwise \end{cases}$$

Now the total number of matched minutiae pair given by,

$$num\ (matched\ minutiae) = \sum mm(m_i, m_j) \quad (8)$$

and final match score is given by,

$$Matched\ Score = \frac{num\ (matched\ minutiae)}{\max(num\ of\ minutiae\ in\ I_1,\ I_2)} \quad (9)$$

VI. RESULTS

Fig 2: Original image

Fig 3: Normalized image

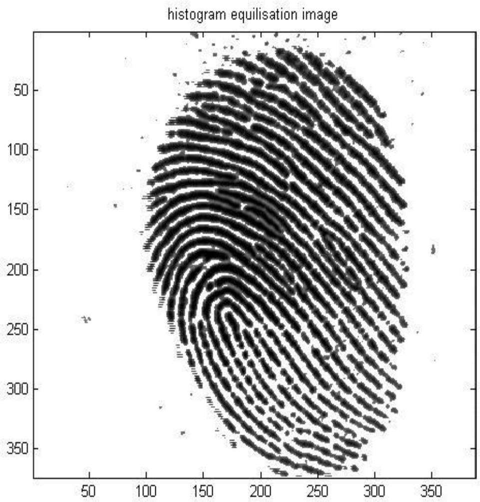

Fig 4: histogram equalization image

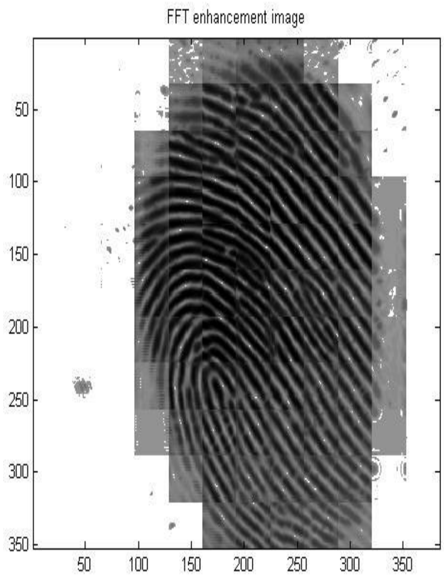

Fig 5: FFT enhancement image

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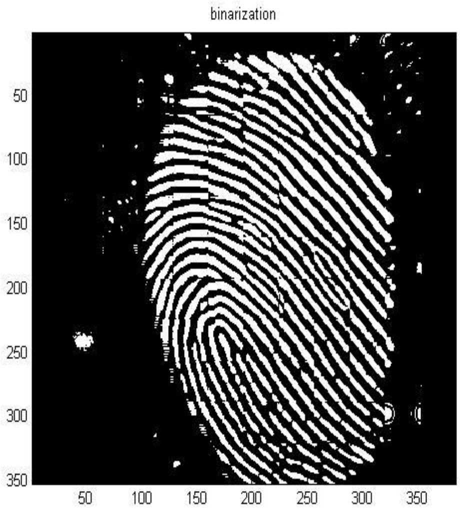

Fig 6: binarized image

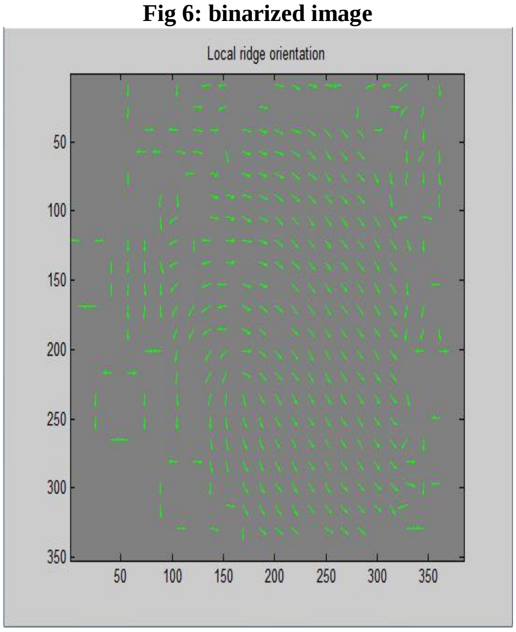

Fig 7: local ridge orientation image

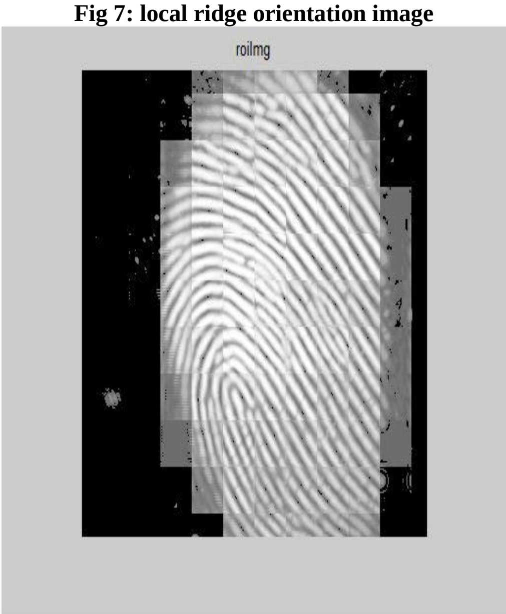

Fig 8: Image after ROI extraction

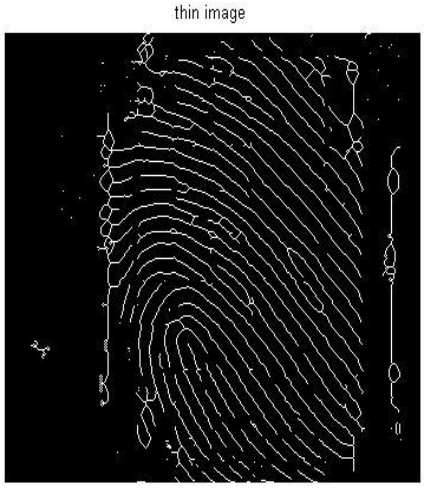

Fig 9: thinned image

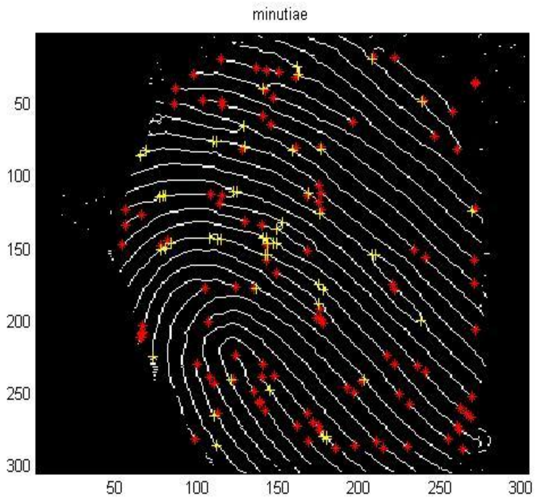

Fig 10: minutiae extraction

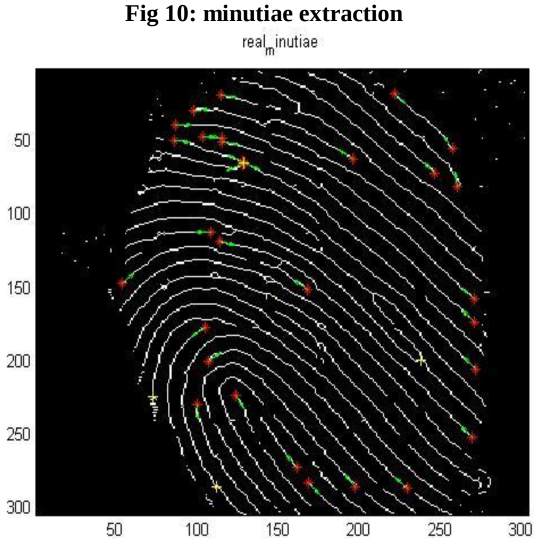

Fig 11: real minutiae

Lower level of matching is due to some fingerprint images with bad quality. Furthermore, good experiment designs can

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surely improve the accuracy. Further studies on good designs of training and testing are expected to improve the result.

VII. CONCLUSION AND FUTURE WORK

Histogram equalization and fast Fourier transform is suited best over normalization because normalization uses hard thresholding to normalize the fingerprint image while fast Fourier transform is implemented locally in a fingerprint image. Segmentation is implemented using gradient magnitude and has better result over segmentation using variance based method. Overall, a set of reliable techniques have implemented for fingerprint image enhancement and minutiae extraction. These techniques can then be used to facilitate the further study of the statistics of fingerprints. The future scope of the work is to improve the quality of image either by improving the hardware to capture the image or by improving the image enhancement techniques, So that the input image to the thinning stage could be made better which can improve the future stages and the final outcome

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