Morphological and gradient based fingerprint image segmentation

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***Abstract*—** For personal identification the use of **f**ingerprint identification systems is mostly common. First step for an Automated Fingerprint Identification System (AFIS) is the segmentation of fingerprint from the acquired image. Extraction of region of interest (ROI) from the desired fingerprint impression is the main purpose of segmentation. In this paper, we present a new technique for fingerprint segmentation using morphological operations and modified gradient based technique. The distinct feature of our technique is that it gives high accuracy for fingerprint segmentation even for low quality fingerprint images. The proposed algorithm is applied on standard fingerprint databases, FVC2002 and FVC2004. Experimental results demonstrate the improved performance of the proposed scheme.

Keywords-component; Segmentation, Region of Interest, Morphological operation, Gradient

I. INTRODUCTION

Due to the feasible use of fingerprint verification systems and the uniqueness of individual's fingerprint, fingerprint based recognition security systems are popular and in demand. [1]. The first stage in these systems is the segmentation of fingerprint which aims at separating foreground from background for the convenience in further processing and for reducing computational cost and time.

Fingertip contains a pattern of ridges and valleys that are parallel to each other and it is known as fingerprint [2]. Fingerprint identification is done using local features such as ridge endings and ridge bifurcations, known as minutiae [3]. The essential part of these systems is segmentation of fingerprint image. Feature extraction algorithms extract a lot of false features (minutiae) when applied to the noisy background area. The purpose of segmentation is to remove background and the noisy area from fingerprint image. It is especially important for the reliable extraction of fingerprint minutiae.

Fingerprint segmentation algorithms are divided into two categories: unsupervised and supervised. Unsupervised algorithms consists of block wise features such as gray-level mean and variance, block wise gradient magnitude [6], local and adaptive histogram of ridge orientation [4],[5] and Gabor feature [7],[8] are extracted. In addition to these features, supervised methods also use a simple linear classifier for classification.

Local certainty level of the orientation field method was described by Jain et. al. [10]. Maio et. al. [11] used the average gradient of fingerprint and decided whether a pixel blongs to foreground or background depending upon its value. In addition to gradient, coherence and mean and variance was used in [12] for fingerprint segmentation. A Gabor filter based approach was presented by Shen et. al. [13].

This paper presents a morphological and Gradient based method for fingerprint segmentation and compares proposed technique with Mean and Variance based technique, Direction based technique [14] and simple gradient based technique [17]. Our technique uses gradient based mean and variance instead of simple mean and variance and then it uses morphological operation to remove single pixel and edge pixel noise. Previously proposed methods give good results in case of suc fingerprints whose ridges are distinct and background is uniform. But these methods do not work well on too wet or too dry fingerprint images.

This paper is organized in five sections. Section 2 presents a brief system overview. Section 3 contains the proposed method for fingerprint segmentation. Experimental results and comparison of our technique with other techniques are discussed in section 4 and finally conclusion in section 5.

II. SYSTEM OVERVIEW

Fingerprint scanners of various resolutions are available but mostly scanners with 500 dpi are used to acquire fingerprint images [18]. The captured fingerprint images from scanners usually contain noise and distortion which may cause in extraction of false features and lowering the matching rate, so this noisy and unwanted area can be discarded by preprocessing i.e. segmentation [16]. That is why this paper presents a novel method for accurate fingerprint segmentation. Figure 1 shows a complete system overview for proposed technique.

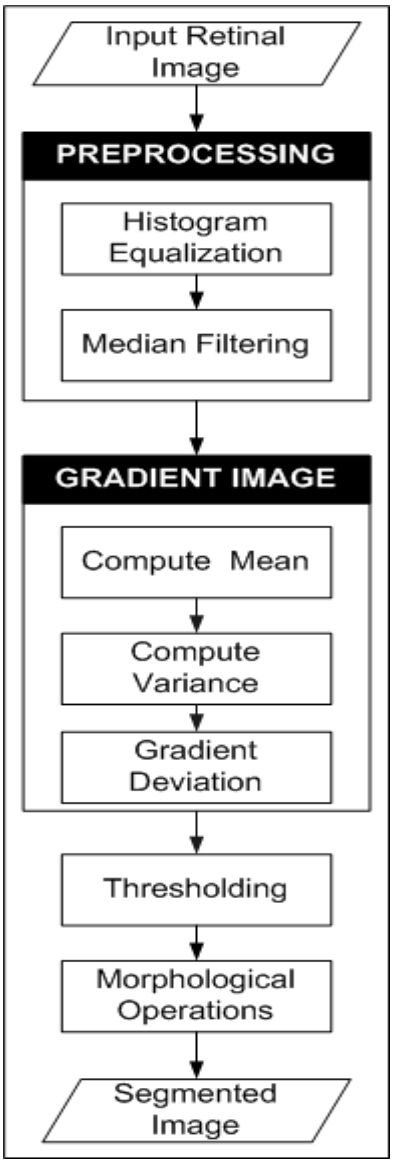

Fig .1 Complete Flowchart of System Overview

III. PROPOSED TECHNIQUE

In Automated fingerprint identification system, it is not necessary to process the background part of image as only foreground contains ridges. Segmenting out the background not only lowers the probability of false minutiae extraction but also reduces the overall processing time. This section presents a new Morphological and Gradient Based Method for fingerprint segmentation. The sharp changes in gray level value are detected by first computing local gradient values for fingerprint image. Fingerprint segmentation is a difficult task especially in case of dry and wet images but proposed technique also accurately segments these types of images.

The proposed technique follows following steps for fingerprint segmentation:

1. Let f(x,y) is the original fingerprint image
2. For local processing, divide the fingerprint image f(x,y) into small non-overlapping blocks of size NxN (Here N = 8).
3. For enhancing the contrast between background and foreground, local and adaptive histogram equalization is used.
4. For removing unwanted artifacts and noise, a 5x5 median filter is used [15].

$$\overline{f}(x,y) = median_{(s,t)\varepsilon Sxy}\{g(s,t)\} \quad (1)$$

5. Sobel vertical and horizontal masks of size 3x3 are used to compute the gradients $\partial x(x,y)$ and $\partial y(x,y)$ at each pixel location (x,y) which is the center of the block. Equations 2 and 3 represents $\partial x(x,y)$ and $\partial y(x,y)$ respectively

$$sobelvertical = \begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{pmatrix} \quad (2)$$

$$sobelhorizontal = \begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix} \quad (3)$$

6. Gradient mean is calculated instead of simple mean as it emphasizes small changes. $\partial x(x,y)$ and $\partial y(x,y)$ are used to compute the mean values $M_{x\ and}$ M_y using equations 4 and 5 respectively.

$$Mx = \frac{1}{N^2}\sum_{x=-N/2}^{N/2}\sum_{y=-N/2}^{N/2}\partial x(x,y) \quad (4)$$

$$My = \frac{1}{N^2}\sum_{x=-N/2}^{N/2}\sum_{y=-N/2}^{N/2}\partial y(x,y) \quad (5)$$

7. Gradient standard deviations for x and y direction are computed with the help of gradient means $M_{x\ and}$ M_y using equations 6 and 7.

$$stdx = \sqrt{\frac{1}{N^2}\sum_{x=-N/2}^{N/2}\sum_{y=-N/2}^{N/2}(\partial x(x,y) - Mx(f))^2} \quad (6)$$

$$stdy = \sqrt{\frac{1}{N^2}\sum_{x=-N/2}^{N/2}\sum_{y=-N/2}^{N/2}(\partial y(x,y) - M(f))^2} \quad (7)$$

8. Finally the overall gradient deviation is computed using equation 8

$$grddev = stdx + stdy \quad (8)$$

9. A threshold value is computed empirically and applied on final gradient deviation. Gradient deviation has a high value for foreground pixels and low value for background pixels.

10. Binary image after thresholding contains single pixel noise and edge pixels. Morphological operations i.e. morphological dilation, morphological erosion and morphological opening are applied to remove single pixel noise from binary masks. We have used a 5 x 5 square structuring element for morphological operations.

Figure 2 shows the two images from FVC 2004 database and segmentation result of proposed method.

Fig. 2. (a): Fingerprint Images, (b): Proposed method Segmented Images

IV. EXPERIMENTAL RESULTS

We have extensively tested our algorithm using standard fingerprint image databases FVC2002 [18] and FVC2004 [19]. Both databases contain overall 640 fingerprint images of different quality. The FVC 2002 database contains images from 40 different persons with 8 impressions of each person (40x8=320 fingerprints). Database is further divided into four sets DB1, DB2, DB3 and DB4 containing 640x480, 296x560, 300x300 and 288x384 respectively and each having a resolution of 500 dpi. Similarly, FVC 2004 also contains images from 40 different persons with 8 impressions of each person (40x8=320 fingerprints). This Database is also further divided into four sets DB1, DB2, DB3 and DB4 containing 640x480, 328x364, 300x480 and 288x384 respectively and each having a resolution of 500 dpi. The proposed method is compared with Mean and Variance based method, simple gradient based method [17] and Direction based method [14]. Comparison results are summarized in table-1 and table-2. Table-2 shows the comparison of these techniques with respect to different background. It is clear that proposed technique performs better with noisy and dark backgrounds where other fails. A comparison of computation time between proposed and previously presented methods is performed and is summarized in Table 3. Figure 3 shows fingerprint segmentation results for fingerprints of different quality. It demonstrates that the proposed technique segmented the ridges with great accuracy as compared to other techniques.

TABLE I. COMPARISON RESULTS I

Approaches	Accurately Segmented (Numbers)	Accurately Segmented (%)	Poorly Segmented (Numbers)	Poorly Segmented (%)
Mean and Variance	423	66.5	214	33.5
Gradient Based	588	91.8	52	8.2
Direction Based	454	71.0	186	29.0
Proposed Segmentation	606	94.6	34	5.4

TABLE II. COMPARISON RESULTS II

Quality of image	Mean and Variance (%)	Gradient Based (%)	Direction Based (%)	Proposed Segmentation (%)
White Background	97	87	95	97
Grayish Background	87	89.3	91	91
Dark Background	6	92	12	92
Noisy Background	42	91.0	57	91

TABLE III. COMPUTATIONAL TIME

Techniques	Processing Time (Seconds)
Mean and Variance	0.27
Direction based Method	0.22
Gradient based Method	0.16
Proposed Segmentation	0.15

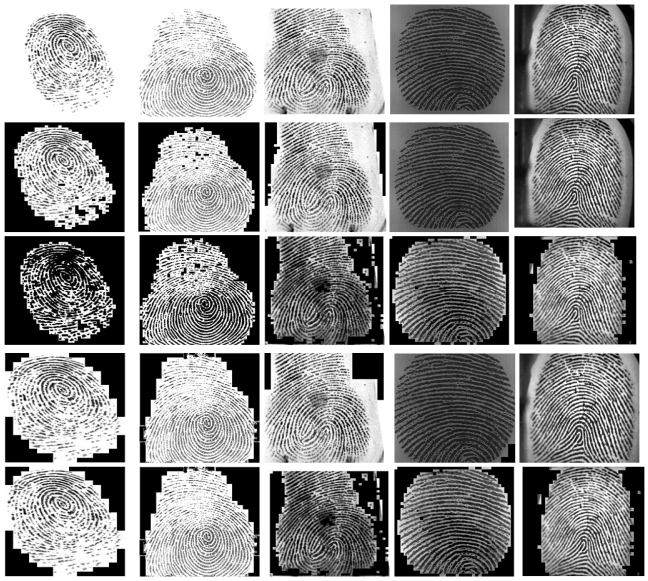

Fig. 3. Fingerprint segmentation results. Ist row shows original fingerprint images from FVC 2002 and FVC2004. 2nd, 3rd and 4th rows show the segmented images with Mean and variance based, Direction based and simple gradient based techniques respectively. 5th row shows the segmented images with Presented Technique

V. CONCLUSION

The performance of AFIS is affected by segmentation of fingerprint image as it removes background effects. This paper proposed a new method based on morphological and gradient operations. The presented segmentation technique detects region of interest standard deviation of gradient image instead of original image and finally morphological operations are used to remove single pixel and edge pixel noise. The segmentation results show that our proposed algorithm segments fingerprints more accurately than the simple mean and variance based method, direction based segmentation technique and simple gradient based method.

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