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A Simple and Novel Fingerprint Image Segmentation Algorithm

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***Abstract*—Fingerprint image segmentation is initial part of fingerprint recognition system. Fingerprint segmentation separates fingerprint area from image background. Segmentation is used to avoid extraction of feature in noisy areas that are common in background. In this paper we propose a very simple algorithm that uses Laplacian of Gaussian (LoG) filter, edge filter (LoG based) and morphological operations. This algorithm does not require block wise computation of mean and variance. Proposed algorithm also take advantage of the fact that most fingerprint images are vertical or within 45 degrees to the vertical. The proposed algorithm is applied on FVC2004-DB1,DB2,DB3 and FVC2000-DB3 public database. Experimental results show that algorithm gives good output even for low quality images.**

***Keywords:* image processing, segmentation, fingerprint**

I. INTRODUCTION

Fingerprints are most widely used biometric because of its distinctiveness and persistence properties. Today every forensic and law enforcing agency uses automatic fingerprint identification systems (AFIS). In AFIS, the input fingerprint image goes through a series of processing steps usually made of segmentation, ridge orientation, singularity and core point detection, enhancement, minutia extraction and matching [1].

Fingerprints are made of ridges and valleys. This constitute the foreground of fingerprint image. The non-fingerprint area or background with noise will produce false features when used in extraction of features like singularity, core point, and minutia. The purpose of segmentation is to remove background area. It is especially important in extraction of core point and minutia.

There are many algorithms in literature for fingerprint segmentation. Many of them are block wise [2-4], which divides fingerprint image in non-overlapping blocks. These algorithm computes block wise mean and variance for segmentation.

II. REVIEW

Fingerprint images are striped and oriented patterns. Hence simple local or global thresholding [5] does not work effectively. Average intensity does not discriminate between foreground and background but it is the presence of striped and oriented patterns in foreground and near uniform pattern in background.

1. Mean and variance based conventional method

This method can segment number of basic images and also preserves discontinuities. But this method does not work well with images with noisy background or excessive dry or wet fingerprint images.

This method can be summarized as follows:

a. Divide fingerprint image M into non overlapping blocks of size mxn.
b. Compute mean of each block using following equation.

$$\text{Mean} = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}[M(i,j)]}{m*n}$$, where M(i,j) is intensity value at i^{th} row and j^{th} column.
c. Compute variance of block using mean value obtained from above step.

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$$\text{Variance} = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}[M(i,j)-Mean]^2}{m*n}$$

d. Threshold the image based on value of variance calculated in above step. If variance is greater than certain threshold block is considered as foreground. Threshold can be selected empirically or any available optimum selection method. Column 2 of fig. 3 shows the results of this method. A high resolution image for fig. 3 is available at [7]. Threshold value is selected is using Otsu's method [8]. It can be seen from the results that this method works well images with uniform background but in images with noisy or dark background, falsely considers background pixels to foreground.

2. Morphology and gradient based method

In [3] authors present morphology and gradient based segmentation method. This method works well with noisy as well as dark backgrounds. But fingerprint images with noisy ridge regions or excessive dry or wet fingerprint images this method does not give satisfactory results. Column 3 of fig. 3 shows results of this method.

This method can be summarized as follows:

a) Divide fingerprint image into non-overlapping blocks of size NxN.

b) Enhance contrast using adaptive histogram equalization.

c) Remove noise using median filter [5] of size 5x5.

d) Compute gradients Gx(*x,y*) and Gy(*x,y*) using 3x3 Sobel horizontal and vertical masks [5].

e) Compute gradient means of Gx and Gy of each NxN block.

$$\text{Mx} = \frac{1}{N^2}\sum_{x=-N/2}^{N/2}\sum_{y=-N/2}^{N/2} \text{Gx}(x,y) \text{ and}$$

$$\text{My} = \frac{1}{N^2}\sum_{x=-N/2}^{N/2}\sum_{y=-N/2}^{N/2} \text{Gy}(x,y)$$

f) Compute standard deviations *stdx* and *stdy* for Gx and Gy using mean values obtained from above step.

$$stdx = \sqrt{\frac{1}{N^2}\sum_{x=-N/2}^{N/2}\sum_{y=-N/2}^{N/2}[\text{Gx}(x,y) - \text{Mx}]^2}$$

$$stdy = \sqrt{\frac{1}{N^2}\sum_{x=-N/2}^{N/2}\sum_{y=-N/2}^{N/2}[\text{Gy}(x,y) - \text{My}]^2}$$

g) Calculate overall standard deviation of gradient *grddev=stdx+stdy.*

h) Threshold the image for segmentation. Threshold value is selected empirically, *grddev* has high value for foreground regions and low values for background regions.

i) Morphological operations i.e. dilation, erosion and opening is used to remove isolated small background regions.

III. Proposed Algorithm Flowchart

Figure 1 shows a flowchart of proposed algorithm. MATLAB demo code for algorithm is available at [6].

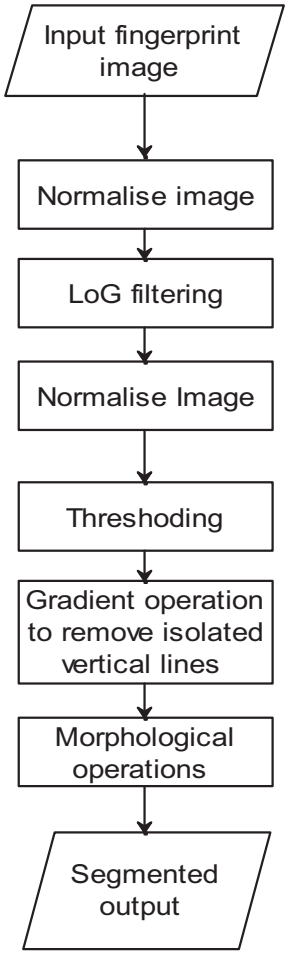

Fig. 1 Flowchart of proposed algorithm

IV. Proposed Algorithm

The proposed algorithm is as follows:

1. Let M be the input fingerprint image.

2. Normalize image M so that the minimum value is 0 and the maximum value is 1.

3. Apply LoG filter to output of step 2. Here we used the sigma (σ) value of 3.5 and 7x7 window. Use lower value of sigma for excessive dry or wet fingerprint images. Filter equation is given by following [5]:

$$\text{LoG}(x,y) = -\frac{1}{\pi\sigma^4}\left[1 - \frac{x^2+y^2}{2\sigma^2}\right] e^{-\frac{x^2+y^2}{2\sigma^2}}$$

4. Again normalize the image of step 3 so that the minimum value is 0 and the maximum value is 1. Figure 2(b) shows the output of this step.

5. Threshold the image of step 4 using LoG edge detection method to get binary image. Default value of sigma is 2. Threshold value is determined empirically. Typical value for thresholds are 0.004 for FVC2004-DB1 and 0.01 for FVC2000-DB3, FVC2004-DB2 and DB3. Figure 2(c) shows the output of this step.

6. Compute gradient in y direction of image obtained in above step. This removes isolated vertical lines in binary image obtained in step 5.

7. Use morphological operations to remove small cluster of noise pixels and retain the largest one. Morphological operations i.e. Morphological fill, closing, dilation are used. Circular structure element of radius 5 is used. Use higher value of radius for excessively dry or wet fingerprint images.

V. Algorithm results

We have tested our algorithm using FVC2004-DB1, DB2, DB3 public databases and FVC2000 DB3 public database. FVC2000 DB3 public database images are of 500 dpi and having size 448x478 pixels, with 10 fingers and 8 impressions per finger. FVC2004 DB1, DB2, DB3 public database images are of 500 dpi, 500 dpi, 512 dpi, having size 640x480, 328x364, 300x480 pixels respectively. These too contains images of 10 fingers and 8 impressions per finger, i.e. 80 images per database.

Figure 3 shows the images from FVC2000 and FVC2004 databases and the segmentation output of proposed algorithm (column 4) along with the results of conventional mean and variance segmentation method (column 2) and method of [3] (column 3) respectively. It can be seen that our proposed algorithm does not produce blocking artifact or isolated background pixels. Comparison results are summarized in table-1 for 320 (80*4=320) fingerprint images.

a

b

c

Fig. 2 Original image from FVC2000 DB3 (a), image from step 4 of algorithm (b), image from step 5 of algorithm (c).

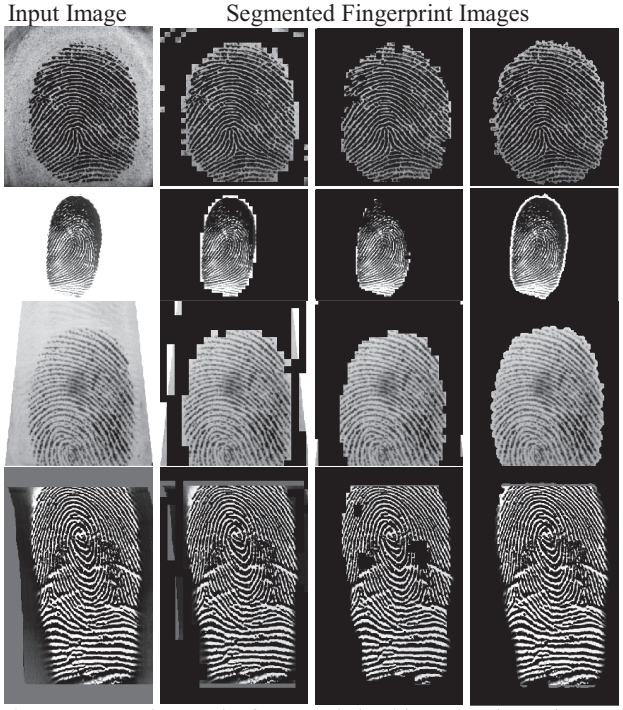

Fig. 3 Segmentation result of proposed algorithm. 1st column shows input fingerprint images from FVC2000-DB3, FVC2004-DB1, DB2, and DB3 respectively. 2nd, 3rd and 4th columns shows segmentation results of conventional mean-variance method, method of [3] and proposed algorithm respectively

TABLE I. COMPARISON RESULTS

Approach	Total Numbers of Images	Accurately Segmented
Mean and Variance based	320	266
Morphology and Gradient based	320	232
Proposed	320	297

VI. CONCLUSION

In this paper we proposed a novel and simple LoG filter and morphological operations based fingerprint image segmentation algorithm. This algorithm does not require block-wise operation or computation of mean and variance. It can be seen from the result that algorithm works well for good quality fingerprint image (2nd row) as well as for low quality fingerprint images (1st and 4th row). Comparing with column 2 and column 3 of fig. 3 we observe that proposed algorithm gives better results for fingerprint images with noisy background or excessively dry or wet fingerprint images and it is much simpler in implementation.

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