Chapter 7

CORRELATION BASED FINGERPRINT IMAGE SEGMENTATION

Segmentation is an important image-processing tool used in machine vision applications like pattern matching and classification. Segmentation leads to separation of area of interest (AOI) from an image using some image parameters. This Chapter describes a new method of segmentation for fingerprint image. Foreground or area of interest consists of oriented structure of ridges and valleys. The AOI segmentation is an important step in process of minutiae extraction. The proposed method of segmentation exploits the relation between the local neighborhoods in a fingerprint by means of correlation and is used to determine the AOI. The performance and effectiveness of the proposed algorithm has been evaluated for fingerprint images from FVC2002 and FVC2000 database. The proposed method of segmentation performs in a better way with less computations and simplicity.

7.1 Introduction

The foreground in a fingerprint image consists of oriented pattern with variations in orientations. In practice a more robust segmentation techniques is required for fingerprint. Some of such fingerprints are shown in Figure 7.1. Few authors have proposed some techniques for fingerprint image segmentation. Some of them have been briefly discussed in Section 1.3.3.
This work presents a new method of foreground segmentation in a fingerprint image, which works on correlation between neighborhood blocks.

### 7.2 Statistical Correlation and its Interpretation

Correlation analysis estimates the degree of relationship or similarity between two or more functions. The coefficient of correlation has been the most useful statistical measure to determine the degree of similarity between two variables or functions. In this work we have used the Karl Pearson's coefficient of correlation [79], and is given by Equation 7.1.

\[
    r = \frac{\sum xy}{\sqrt{\sum x^2 \sum y^2}} \tag{7.1}
\]

where, \( x = X - \mu_X \) and \( y = Y - \mu_Y \) where, \( X \) and \( Y \) are the two vectors with statistical mean \( \mu_X \) and \( \mu_Y \) respectively. Also the coefficient of correlation is said to be a measure of covariance between two variables (Equations 7.2 and 7.3).
\[ r = \frac{\sum xy}{N\sigma_X\sigma_Y} \]  

(7.2)

where,

\[ \text{covariance} = \frac{\sum xy}{N} \]  

(7.3)

where, \( x = X - \mu_X \) and \( y = Y - \mu_Y \), \( N \) is size of vectors, \( \sigma_X \) and \( \sigma_Y \) are standard deviations of vectors \( X \) and \( Y \) respectively.

The value of Karl Pearson coefficient of correlation \( r \) appears between +1 and -1. When \( r = +1 \) it means there is perfect positive correlation while if \( r = -1 \) there exists a perfect negative correlation and if \( r = 0 \) means there is no correlation.

### 7.3 Correlation Based Segmentation

Foreground in a fingerprint image is represented as an area with maximum variance while there is uniform or zero (minimum) variance in background [25]. Hence there exists a definite correlation between the local neighborhoods in foreground in a fingerprint. The correlation between the local neighborhoods has been used as basis for foreground segmentation. The segmentation has been performed locally (as fingerprint consists variations in ridge directions locally). The fingerprint image has been divided into square blocks. The size of a block depends on image specifications like resolution. The care has been taken such that each block should contain at least one ridge and one valley. In this work a block size of 10 x 10 pixels has been used. A grids of 3 x 3 blocks have been considered for segmentation as shown in Figure 7.2.

The correlation coefficient between center block and all eight neighboring blocks has been computed using following Equation.

\[ r(i, j) = \frac{\sum_{i=1}^{m} \sum_{j=1}^{n} x^{\left(\frac{m+1}{2}, \frac{n+1}{2}\right)}y(i, j)}{\sqrt{\sum_{i=1}^{m} \sum_{j=1}^{n} x^{\left(\frac{m+1}{2}, \frac{n+1}{2}\right)}^2 \sum_{i=1}^{m} \sum_{j=1}^{n} y(i, j)^2}} \]  

(7.4)
Figure 7.2: Grid used for computation of correlation.
where, $m = n = 3$. If $r(i,j) < T$ (Threshold), then the two blocks (center block and $(i,j)$th block) belongs to the foreground and are treated as a segment of foreground. For foreground the correlation coefficient between the neighborhood blocks results into a positive value less than 1 (typically 0.45).

A $5 \times 5$ structuring morphological operators (closing operation) has been used for eliminating the holes. Later foreground has been segmented based on morphological mask. The steps in correlation based segmentation has been illustrated in Figure 7.4

### 7.4 Experimental Results and Conclusions

The proposed algorithm has been tested for more than 2000 images. The databases used for experimentation are FVC2002 (DB1.a and DB1.b) and FVC2000 (DB2). Further the algorithm has been tested on the database in which the fingerprint images have been captured using Hamster scanner (around 352 images). The database consist of number of poor quality (by means of average gray levels and clarity in ridges) fingerprint images. Some of the results of correlation based segmentation are shown in Figure 7.4.

The proposed algorithm utilizes the correlation between the neighborhood blocks for segmentation of foreground in fingerprint image. This algorithm is capable of segmenting effectively fingerprint images of quality good, poor and dry as shown in Figure 7.4. It also works satisfactorily for images with uniform background. The algorithm is capable of performing satisfactorily on raw fingerprint images without any preprocessing. This method of segmentation works irrespective to the variations in gray level values. The computations required for segmentation by proposed method are very less. In the algorithm the size of grid, size of block and threshold may vary for different databases.
Figure 7.3: Steps involved in Correlation based segmentation. (a) original image (b) correlation image (c) image after applying 5x5 morphological operator (d) segmented image using morphological mask.
Figure 7.4: Some results of segmentation algorithm. (a),(b) segmented image and original image of good quality (c),(d) segmented image and original image of poor quality (dry) (e),(f) segmented image and original image of moderate quality.