AN EVALUATION ON THE SURVEY REPORTS OF FINGERPRINT IMAGE SEGMENTATION TECHNIQUES

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ABSTRACT

Along with the technological advancement, the reliable individual recognition and identification system became very important. Many biometric characteristics can be used: iris, face, fingerprint, voice, gait etc. From the various biometric characteristics, fingerprint is one of the popular methods as the fingerprint sensors are relatively much more economical than others. Despite of the constant research carried out in the field of fingerprint, still there are open challenges to be solved. Almost every automatic biometric identification system works by extracting features from the input image. A fingerprint image is obtained by a sensor which contains two areas, a foreground and a background area. The foreground is the region obtained by pressing the fingertip on the sensor. The background is usually the noisy area at the borders of the image. Automatic Fingerprint Identification System (AFIS) that makes use of a feature extraction algorithm tries to extract only Region of Interest (ROI) by eliminating the false features. Fingerprint matching is carried out by extracting feature points which can be local or global. So, fingerprint image segmentation plays an inevitable role in the extraction of valid features. This work proposes to have an overview of some of the fingerprint segmentation techniques available in literature. These algorithms are discussed and compared based on their performance in this paper.

Keywords : fingerprint, segmentation, feature extraction

I. INTRODUCTION

Along with the technological advancement, the reliable individual recognition and identification system became very important. Many biometric characteristics can be used: iris, face, fingerprint, voice, gait etc. From the various biometric characteristics, fingerprint is one of the popular methods as the fingerprint sensors are relatively much more economical than others. A Fingerprint is a unique arrangement of ridges and valleys. A ridge is a curved line and the area between two neighbouring ridges is called a valley. A fingerprint verification system consists of four major steps: *image acquisition*, *pre-processing*, *feature extraction* and *matching*. The captured fingerprint image is made up of two parts: i) the foreground and ii) the background (see fig.1). The foreground area is obtained directly by pressing the fingertip against the surface of the scanner. The background area contains more noise when compared to the

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foreground. Fingerprint matching is carried out by extracting feature points which can be local or global. So, fingerprint image segmentation plays an inevitable role in the extraction of valid features.

This paper is organized according the following sections. Section II contains various fingerprint image segmentation techniques available in literature. Some commonly known segmentation algorithms are briefly compared in Section III. Section IV discusses some experimental results. Finally Section V gives the conclusion.

Figure 1. A fingerprint imag

II. Fingerprint Segmentation Techniques

A number of techniques related to fingerprint image segmentation are available in literature. In [1], a segmentation algorithm based on local pixel features like mean, variance and coherence is proposed. Then, these features are combined in a linear fashion for segmentation. The limitation of this technique is its low speed. The coherence feature shows whether the ridge orientations are keeping the same direction. The coherence measure is more in the foreground when compared to the background area. So, taking into account only the coherence feature will not lead to robust segmentation. In [2], from the acquired fingerprint image Gabor features, Gabor response is very high in the foreground area. But, this method is computationally costly. In [3] a feature known as block clusters degree (CluD) is mentioned. CluD tells whether the ridge pixels can be clustered. In [4], it can be seen that Harris point feature is much stronger in foreground when compared to the background area. In [5] the correlation between local neighbourhoods is used as the basic idea for segmenting the foreground area.

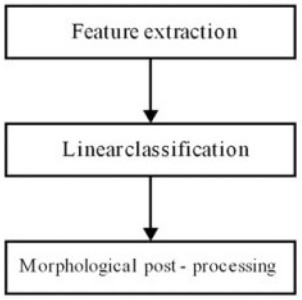


Figure 2. Block diagram of the segmentation algorithm

A. Technique based on three-pixel features

The method in [1] uses three pixel-based features, namely the coherence, the mean and the variance. The classification step is conducted using an appropriate linear classifier. Morphology is applied

as post processing step to obtain compact clusters and to lessen the mis-classifications ratio.

The coherence can specify if the gradients along the ridges are oriented in the same direction. A fingerprint basically consists of parallel ridge-valley structure, so the coherence will be substantially higher in the foreground when compared to the background. In a window W around a pixel, the coherence is defined as:

$$Coh = \frac{|\sum_W (G_{s,x}, G_{s,y})|}{\sum_W |(G_{s,x}, G_{s,y})|} = \frac{\sqrt{(G_{xx} - G_{yy})^2 + 4G_{xy}^2}}{G_{xx} + G_{yy}} \quad (1)$$

where $G_{s,x}$ is the squared gradient, $G_{xx} = \sum_w G^2_{x,x}$, $G_{yy} = \sum_w G^2_{y,y}$, $G_{xy} = \sum_w G_x G_y$.

The fingerprint images can also be segmented using the mean value. The ridge-valley structures can be approximated by black and white lines. Usually the background region is white in colour as they do not touch the sensor. This means that the mean gray value in the foreground is darker gray, when compared to in the background. Using I as the intensity of the image, the local mean for each pixel is given by:

$$M(I) = \frac{1}{MN} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} I(i,j) \quad (2)$$

Next the variance is used for segmentation in this algorithm. In general, the value of variance of the ridge-valley structures in the foreground area is comparatively very high than the value of variance in the background. The variance is computed by:

$$V(I) = \frac{1}{MN} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (I(i,j) - M(i,j))^2 \quad (3)$$

B. Technique based on Gabor filters

Another important feature mostly taken for segmentation is presented in [2]. It is based on the key feature called Gabor filters. This algorithm computes the outputs obtained from eight oriented Gabor filters. It then determines if a block falls into the foreground region or to the background region. Here some modifications are made to the traditional Gabor filter based technique, i.e.: (i) overlapped blocks, (ii) ridge frequency computation, and (iii) heuristic constraints.

A block of size $W \times W$ with an overlap block size of $W/2$ pixels is calculated. As a result, 4 different Gabor features for each $W/2 \times W/2$ block of the image can be computed. Later these values are used to find the mean value. The value of the local frequency field calculated from the fingerprint is obtained and later on these calculated values are taken as Gabor filter parameters. The block which are not suited for the frequency estimation algorithm are imposed to Heuristic constraints.

C. Technique based on block features: CluD

The steps in this fingerprint segmentation algorithm as in [3] are depicted in the fig. 2. The input fingerprint image is divided to form smaller regions of size $W \times W$ pixels. The three most commonly used features that give meaningful information for segmentation process are the block clusters degree, the block mean and the block variance. The block clusters degree CluD gives the value of how good the pixels in the input fingerprint image cluster

or group together. This is followed by linear classification. Morphological step is performed after segmentation to reduce the classification errors.

D. Technique based on Harris point feature

Harris corner point feature is used in [4] to separate the foreground from the background. The basic underlying idea is that bifurcation ridge endings usually show greater values for Harris corner points. Sometimes the points at the background have higher strength; such points can be separated out using the corresponding Gabor response. The strength of this algorithm is its robustness even in the low quality images, keeping the required ROI. Moreover, this segmentation algorithm could also filter out spurious boundary minutiae points effectively. Translating a window through the corners in any direction could give wide variations in the intensity value. Therefore, a corner point can be easily identified by considering the intensity values of the local neighbourhood. The various Harris corner points that are present in the foreground region can be connected together using Convex Hull algorithm. It is observed in this work that the measure of Harris point in the foreground area is much more than that of in the background area. In order to detect these points, the measure of corner response is calculated and is given by:

$$R = \frac{Det(M)}{Trace(M)} = \frac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2} \qquad (4)$$

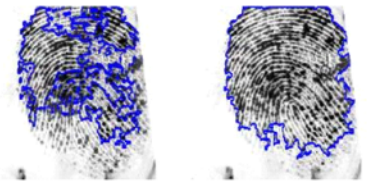
where M is the auto-correlation matrix, which stores pattern of the ridges of nearby neighbourhood. With respect to the eigen values (λ_1,λ_2) of M, points of interest are calculated in such a way that (i) the eigen values are high and (ii) the corner strength is a maximum in a 3 × 3 local neighbourhood.

E. Technique based on Correlation

In a fingerprint input image, foreground area reflects the maximum intensity variance, while background shows zero or uniform variance. So, there exists a strong correlation between the nearby pixels in the foreground. Thus it can state that the correlation between pixels in a neighbourhood is a good candidate for foreground segmentation. The segmentation is achieved locally by characterizing the variations along ridge directions. To compute the correlation based segmentation, the fingerprint image is grouped into square block based on image

Table 1. Comparison of various segmentation techniques

Reference	*Algorithm*	*Parameters*	*Advantages*	*Limitations*	*Complexities*
1	3- pixel feature	Mean, Variance, Coherence	Accurate results	Pixels misclassified	Post-processing needed
2	Gabor Filters	Gabor Features	Valid blocks preserved in foreground	Low-quality images	Post-processing needed
3	CluD	Mean, Variance, block cluster degree	Faster and accurate results in segmentation	Pixels misclassified	Post-processing needed
4	Harris Point Feature	Harris corner feature	Good results for low- quality images	low-contrast images	Heuristic and Convex hall algorithm needed
5	Correlation	Correlation	Good results for low-quality images	Pixels misclassified	Post-processing needed



(a) (b)

Figure 3. (a) Before morphology operation (b) After morphology operation.

size. It is emphasized that each block contains at least one ridge and one valley pattern.

So, in [5] the algorithm uses ridge orientation for segmenting the foreground from its background. A 5×5 morphological structuring element is used for clustering the segmented regions in the fingerprint image by eliminating holes. Finally, foreground is segmented using the morphological operations.

III. COMPARISON OF VARIOUS FINGERPRINT SEGMENTATION TECHNIQUES

The comparisons of various fingerprint segmentation techniques are stated in the Table I. It provides a brief comparison of some of the segmentation techniques available in literature. Table I specify the advantages, limitations and complexities of the algorithms.

IV. RESULTS AND EXPERIMENTS

Fig. 3(b) shows the result of some segmented fingerprint image after the post-processing step. Fig. 4 illustrates results after fingerprint segmentation. The fingerprint segmentation method has been experimented on a sample set of fingerprint images taken form Neurotechnologija web site [8] named Verifinger Sample DB. This data set contains a total of 520 fingerprint images (8 different fingers of 65 persons). To measure the performance of the segmentation algorithm, initially the study has manually identified the foreground and the background areas.

V. CONCLUSION

Every automatic fingerprint identification system precedes a fingerprint segmentation step in its pre-processing phase. The

(a) (b) (c)

Figure 4. Segmentation results of some fingerprints image

objective of fingerprint segmentation is to separate the fingerprint ridge like area from its background. Accuracy of an automatic segmentation also depends on how well it includes the feature points of an image. In this paper, various fingerprint segmentation method is presented. This work has compared the various fingerprint segmentation techniques avail-

able in literature. These algorithms are discussed and compared based on their performance. Each technique has a different accuracy of segmenting fingerprint image. This paper presents the critical review of various fingerprint segmentation techniques, stating all the advantages, limitations and complexities of the algorithm

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