CORE POINT DETECTION IN FINGERPRINT IMAGES

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Abstract—Biometrics is a science that deals with identification of humans based on some of their physiological and behavioral characteristics. These characteristics are unique for each person, even for identical twins and hence they form the basis of biometric authentication. Some of these characteristics include fingerprints, iris patterns, retinal blood vessels patterns, hand geometry, palm print, gait etc. Of these, fingerprints found on human fingertips have been the focus of attention of researchers for generations. Fingerprint recognition requires the two images to be aligned before they could be matched with each other. This can be achieved using either external factors or internal characteristics of the fingerprints. Fingerprints consist of certain special regions where the geometry of the ridge structure is very different from that found in other regions. Such regions are called as Singular Points or SPs which can be either core or delta. These regions can be effectively used for fingerprint alignment as they are intrinsic to the fingerprint. Along with the alignment task, these region can also be used for fingerprint classification, fingerprint registration, fingerprint image indexing, fingerprint alignment, ridge frequency determination, ridge counting, database search time and search space reduction etc. The algorithm used to determine the core point in this paper is the Direction of Curvature algorithm. Fingerprints from the FVC-2004 database have been used to test the working of the implemented algorithm.

Index Terms—Fingerprints, Core point, Direction of Curvature, Image Processing.

I. INTRODUCTION

FINGERPRINT based identification has been a hotbed for applications in the field of biometric technology. A fingerprint consists of a pattern of ridges and furrows. When examined on a minute scale, the characteristics of these ridges and furrows constitute what is known as minutiae. At a broader level, fingerprint patterns assume different and distinctive shapes in different areas. These areas are unique when observed according to the pattern of curvature, bifurcation, termination and so on. These distinctive shapes can be categorized into three main topologies: delta, loop and whorl. These kinds of regions are termed as singular regions.

The core point of fingerprints plays an important role in techniques involving fingerprint identification. It has vast applications and is widely used in fields like fingerprint classification [1], and fingerprint matching [2, 3]. In many of these applications, there is no need to detect the exact core point of the fingerprint. Detection a Region of interest or ROI around the core point area is sufficient for these types of applications. However, some applications require exact and precise detection of core point. Accurate core point detection is vital in applications relating to fingerprint classification [1].

Core points are the points where the innermost ridge loops are the steepest. Delta points are those points from which the three patterns – delta, loop and whorl topologies deviate. Figure 1 below represents these core and delta points.

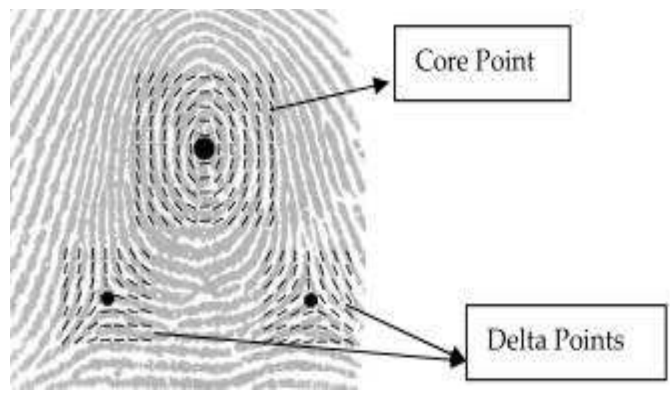

Fig1: Core and Delta points on a fingerprint image [4]

This paper is organized as follows. Section 2 describes fingerprint pre-processing steps viz. fingerprint segmentation and fingerprint normalization. Section 3 describes the steps taken to determine the orientation of ridges within the fingerprint. Section 4 focuses on the Direction of Curvature (DC) algorithm used to determine the core point of the fingerprint. Section 5 deals with the evaluation of ideas and experimental results. Section 6 details the related work and compares and contrasts different algorithms and techniques. The conclusion and future work is described in Section 7.

II. FINGERPRINT PRE-PROCESSING

A. Fingerprint Image Segmentation

Fingerprint segmentation [5, 6], is the first step towards the core point detection. In this process, the background or the non-fingerprint area of the image is separated from the foreground or the fingerprint area of the image. The foreground regions correspond to the fingerprint area which contains the ridges and valleys and the areas of interest. However, the background pertains to the region outside this fingerprint area and does not contain any valuable fingerprint information. Therefore, eliminating this area from the image for further processing reduces the number of operations that need to be performed on the fingerprint image, thus increasing the efficiency and execution time of the algorithm. In this paper, a variance threshold method is used to separate background from foreground. This is because the background region generally shows very low variance, whereas the foreground or the fingerprint region is characterized by a high variance value. The steps used to perform the segmentation are as follows:

a) Read the Image img (i, j) and divide it into non-overlapping blocks of wxw.

b) Calculate the mean value of pixel intensities for each block. The following equation can be used:

$$Mean = M(I) = \frac{1}{w^2} \sum_{i=-w/2}^{w/2} \sum_{j=-w/2}^{w/2} img\ (i,j)$$

c) The calculated mean value is then used to estimate the variance value of each block as follows:

$$Variance = V(I) = \frac{1}{w^2} \sum_{i=-w/2}^{w/2} \sum_{j=-w/2}^{w/2} img\ (i,j) - M(I)]^2$$

d) A variance threshold value is chosen empirically. If the calculated variance for each block is less than the chosen threshold value, then that block belongs to the background. If the variance value is greater than that of the threshold value, then that block will belong to the foreground, and will be used for further processing.

Figure 2 below depicts the output of the implemented fingerprint image segmentation.

Figure 2: Fingerprint area extraction after image segmentation

B. Fingerprint Image Normalization

Normalization is the process of changing the range of the pixel intensity values [7]. The main purpose of normalization is to reduce the variations in gray-level values along the ridges and valleys. The image is normalized to a constant mean and variance value. Normalization is done to reduce the effects of sensor noise and finger pressure difference when taking the fingerprint. Since normalization is a linear pixel-wise operation, it does not change the clarity of the ridge and valley structures of the fingerprint. This paper implements normalization on a per-pixel basis. However, a sub-block of size wxw may also be defined and normalization can then be done on a per-block basis, saving computation time.

Let img(i,j) represent the pixel intensity value at pixel (i,j). Let M_i and V_i denote the estimated Mean and Variance values respectively, from the image segmentation process. If N(i,j) denotes the normalized gray-scale values at pixel (i,j), then the normalized image is defined as follows:

$$N(i,j) = \begin{cases} M_0 + \sqrt{V_0(img(i,j) - M_i)^2} & if\ img(i,j) > M \\ M_0 - \sqrt{V_0(img(i,j) - M_i)^2} & otherwise \end{cases}$$

Here M_0 and V_0 are the desired mean and variance values respectively. $M_0 = 100$ and $V_0 = 100$ are the values used in this paper. Figure 3 below shows the normalized fingerprint image.

Figure 3: Fingerprint Image after Normalization.

III. RIDGE ORIENTATION ESTIMATION AND SMOOTHING

Ridge orientation estimation [7], is a major step towards fingerprint core point detection. Ridges and valleys follow a flow-like pattern. They exhibit orientation ranging from 0 to 180 degrees.

Let θ be defined as the orientation field of a fingerprint image. θ (i,j) represents the local ridge at pixel (i,j). However, it is better to define the local ridge for a block, rather than for each individual pixel. Therefore, the fingerprint image is divided into wxw non-overlapping blocks. The algorithm used in this paper is summarized below:

a) Divide the input image into non-overlapping blocks with size wxw.

b) The gradients δ_x and δ_y are calculated for each pixel in the block. The gradient operator used in this paper is the sobel operator [14], where,

$$Gx = \begin{matrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 0 \end{matrix}\ and\ Gy = \begin{matrix} -1 & 2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{matrix}$$

are the sobel operator filters used.

c) The local field orientation is estimated using the following equations:

$$V_x = \sum_{u=i-w/2}^{i+w/2} \sum_{v=i-w/2}^{i+w/2} 2\delta_x(u,v)\delta_y(u,v)$$

$$V_y = \sum_{u=i-w/2}^{i+w/2} \sum_{v=i-w/2}^{i+w/2} \delta_x^2(u,v)\delta_y{}^2(u,v)$$

From the above values, the orientation field is estimated as:

$$\theta\ (i,j) = \frac{1}{2}\tan^{-1}\frac{V_y(i,j)}{V_x(i,j)}$$

Here, θ is the least square estimate of the local orientation of the block centered at pixel (i,j).

d) There could be discontinuity in the orientation field due to effects of noise. This effect can be reduced or softened using a low-pass filter. However, in order to apply a low-pass filter, the orientation field must first be converted to a continuous vector field. This vector field is defined as:

$\emptyset_x(i,j) = \cos(2\theta(i,j))$, and,

$\emptyset_y\ (i,j) = \sin(2\theta(i,j))$.

e) The low pass filter is then applied to the resulting vector field. The filter is of size hxh. Therefore,

$$\emptyset'_x = \sum_{u=-h/2}^{h/2} \sum_{v=-h/2}^{h/2} G(u,v).\emptyset_x(i-uw, j-vw)$$

$$\emptyset'_y = \sum_{u=-h/2}^{h/2} \sum_{v=-h/2}^{h/2} G(u,v).\emptyset_y(i-uw, j-vw)$$

f) Therefore, the smoothened orientation field can be obtained. It is then computed as:

$$\theta'(i,j) = \frac{1}{2}\tan^{-1}\frac{\emptyset'_y(i,j)}{\emptyset'_x(i,j)}$$

Figure 4 depicts the obtained orientation fields. The orientation field will now be used in the process of detecting the core point of the fingerprint. Therefore, orientation field estimation is a vital step in the path to core point detection of fingerprints.

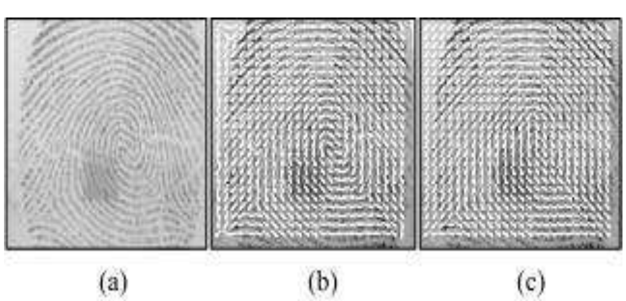

Figure 4: a) Pre-processed image b) Orientation Field Estimation c) Orientation Field Smoothing [7].

IV. CORE POINT DETECTION

For the detection of core point, the Detection of Curvature (DC) algorithm is used. The paper implements the DC algorithm as follows:

a) Compute the local ridge orientation θ(i,j) as described in the previous section. Input block size used was: wxw = 3x3.

b) Smooth the orientation field to compute $\theta'(i,j)$ as shown in Section 3.

c) For every block, the difference of the direction components is computed. This is done as follows:

$$Diff\ Y = \sum_{k=1}^{3} sin2\theta(k,3) - \sum_{k=1}^{3} sin2\theta(k,1)$$

$$Diff\ X = \sum_{l=1}^{3} cos2\theta(3,l) - \sum_{l=1}^{3} cos2\theta(1,l)$$

d) Using the two equations given above, the coordinates of the curvature point (C) can be located. This is done by checking where both Diff X and Diff Y are negative.

The Direction of Curvature (DC) algorithm is simple to implement, but is not a hundred percent accurate. If the application does not depend on the exact core point location, then the fingerprint image can be cropped into a 100x100 rectangle with its center point as the curvature point (C). This rectangle is called the region of interest.

However, if the application requires the exact location of the core point, then this region of interest (ROI) can be further processed with better algorithms like the Geometry of Region Technique (GR) [7,9], or the Poincare Index method [10] could also be used. The paper does not implement these algorithms, and determines the core point of the image based on the Direction of Curvature algorithm.

V. EVALUATION AND EXPERIMENTAL RESULTS

The algorithm implemented in this paper was tested on sample fingerprint images from the FVC-2004 Database [11]. The algorithm was implemented using MATLAB 7.5.0. The implemented algorithm has good success, and was able to identify the core points of the fingerprint images.

The results are shown in the figures below:

Figure 5: Original Sample Fingerprint Image.

The fingerprint shown in figure 5 is used to illustrate the results.

Figure 6: Image after Segmentation

The image after segmentation has no background area, and consists only of the fingerprint area for further processing.

Figure 7: Image after Normalization.

The normalized image is now used to estimate the ridge orientation and further processing leading to the core point detection.

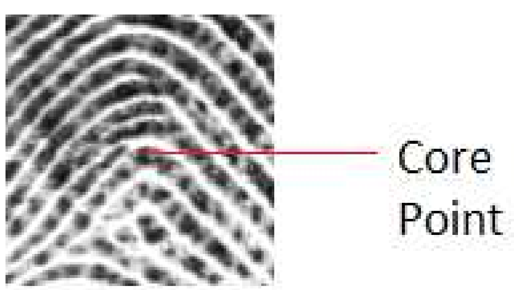

Figure 8: Region of Interest extracted from Image.

The Region of Interest obtained can be further processed with better optimization techniques to determine the exact location of core point. Techniques like Geometry of Region (GR) or Poincare index methods can be used.

Figure 9: Core point location using Detection of Curvature (DC)

As can be seen from Figure 9, the location of core point in the fingerprint is fairly accurate, thus proving the efficiency of the used algorithm.

VI. RELATED WORK

Since core point detection in fingerprint images is a very popular and vital area of research, significant amount of work has been done in the past on this area.

Atipat Julasayvake et.al. [7], have used a combination of the Direction of Curvature (DC) and Geometry of Region (GR) techniques to precisely determine the location of core point. They use the DC algorithm to extract the region of interest (ROI) from the fingerprint image. Then, the ROI is further processed using the GR technique to determine the precise location of the core point. However, this paper has implemented a similar algorithm, but uses the DC algorithm to find the core point location and ROI. It does not use the GR technique.

Navrit et.al [4] have proposed a novel method for Fingerprint core point Detection. In their proposed algorithm, they divide the image into wxw sized blocks, and then determine the direction of gravity of progressive blocks as follows:

$$A = \sum_{k=0}^{P-1} \sum_{l=0}^{P-1} V_x$$

$$B = \sum_{k=0}^{P-1} \sum_{l=0}^{P-1} V_y$$

P is the gravity of progressive blocks. V_x and V_y are derived the same way in [7] and in this paper. Then they use the slope values of each block to determine the block with maximum slope, which corresponds to the core point block.

Arnab et.al [9] implement a robust algorithm for fingerprint core point detection using the Poincare index method. Baig et.al [6] use the corner strength technique with dynamic thresholding to determine the core point location. Guo et.al [8] use the edge map obtained from filtering the fingerprint image using a edge detector to detect the fingerprint core point location. Other algorithms exist which use sophisticated fingerprint segmentation techniques motivated by morphological operations such as erosion, dilation, opening and closing.

Thus, there are many different techniques, and many steps involved in the process of core point detection. An optimal and efficient use of these techniques based on the type of application targeted will result in good performance of the entire algorithm.

VII. Conclusion & future work

The problem studied and implemented by this paper is Core point detection in fingerprint images. This paper has explored and considered various techniques involved in the different steps leading towards core point detection. The algorithm used is motivated by the following factors: simplicity, ease of computation, and good efficiency. The algorithm targets applications where detection of the Region of Interest (ROI) or a coarse location of the core-point is sufficient. Therefore, with the type of application in mind, a simple, robust and efficient algorithm was chosen to implement the problem of core point detection.

Fingerprint segmentation was done based on Variance thresholding, and is based on the fact that background pixels do not have much variance, whereas foreground pixels have a high variance value.

The next step was fingerprint normalization, where the segmented image was normalized to a constant mean and variance value. This was done to eliminate effects of sensor noise, and finger pressure differences at the time of taking the fingerprint.

The third step in the algorithm was the estimation and smoothening of the orientation field. This was done by calculating the gradients in each wxw block of the image. The gradients were calculated using the sobel operator [14]. Then the orientation field was smoothened out and made continuous for further processing.

The last step in the algorithm was the detection of the core point and the Region of Interest (ROI), using the Direction of Curvature (DC) algorithm.

Core point detection in fingerprint images is a promising research area, and opens up a lot of scope and opportunity for future work. A performance comprehensive comparison between the existing techniques for core point detection could be done, as using the optimal technique for the given type of application is crucial to the efficiency of the algorithm as a whole.

Better segmentation and normalization techniques could be explored, because many of the existing techniques, including the one used in this paper fail when the fingerprint image is heavily distorted by noise, or is too light because of low finger pressure at the time of taking the fingerprint. In such cases, the process of ridge orientation estimation, and ROI & core point detection becomes heavily dependent of fingerprint pre-processing techniques, and without good segmentation and normalization methods, the whole algorithm would fail.

Finally, using a combination of core point detection algorithms like that used in [7] can be explored in further depth and detail.

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