Finger-Knuckle-Print Region of Interest Segmentation using Gradient Field Orientation & Coherence

H B Kekre¹, V A Bharadi²
Department of Computer Science
Mukesh Patel School of Technology Management & Engineering, NMIMS University
Mumbai, India
hbkekre@yahoo.com¹, vinu_bharadi@rediffmail.com²

Abstract—Finger-knuckle-print is one of the emerging biometric traits. The region of interest is the area where the maximum information is centered, for a finger knuckle it is the area surrounding the knuckle region. A good system needs this region of interest as input for the feature vector extraction. In this method we present a novel approach for segmentation of Region of interest (ROI) of a finger-knuckle-print using gradient field orientation & its local field strength. This approach is fast and gives good results in case of shift in finger-knuckle-placement (translational shift).

Keywords- Biometrics, Finger-knuckle-print, ROI Segmentation, Gradient Directions, Coherence.

I. INTRODUCTION

The security of a system has three primary components - authentication, authorization, and accountability. Authentication is the most fundamental of these three elements because it comes first [1][2]. In the information technology domain, authentication means either the process of verifying the identities of communicating equipment, or verifying the identities of the equipment’s users which are primarily humans. Biometric systems are becoming popular as a measure to identify human being by measuring one’s physiological or behavioral characteristics[3][4]. Biometrics identifies the person by what the person is rather than what the person carries, unlike the conventional authorization systems like smart cards.

Finger-Knuckle-Print (hereafter referred as FKP) is one of emerging biometric traits, as scanner or capturing hardware for this has been developed and database for research purpose is available [7]. Typical Knuckle-Print image is shown in Fig. 1, taken from the PolyU FKP database. To implement a good biometric security system, we need to verify the biometric trait using feature vector [1][2][7][8]. The feature vector is the information extracted from captured data. To extract the feature vector we need to segment the region of interest which contains information relevant for feature extraction.

In this paper we have proposed a method to segment the ROI using the gradient field based parameters. We have used the gradient orientation which is the local direction of the gradient field and the local gradient field strength for localizing the ROI. In the coming sections we discuss existing methods for the FKP ROI Segmentation and our technique in detail.

II. FINGER-KNUCKLE-PRINT AS A BIOMETRIC TRAIT

FKP being recent has been yet to be thoroughly discovered. The current research has shown great potential in FKP to be used as an efficient and accurate biometric trait [8][9][10][11]. Hand geometry, especially 3D features from finger surface has been used in [12][13] as a biometric traits but specific localized part has not been proposed. Ravikanth & Kumar [14] have proposed use of finger back surface as biometric feature; the whole back surface of hand is captured and then pre-processed to isolate the finger knuckle. They used subspace analysis using PCA & LDA for FKP analysis, in [10] L. Zang et al. have discussed this as an sub-optimal approach for FKP verification.

L. Zang et al. have captured FKP using a specially developed device which essentially captures finger knuckle print area around the finger knuckle.

Figure 1. Typical Finge-Knuckle-Print Image from Hong Kong Polytechnic University FKP Database[7].

Figure 2. Region of Interest (ROI) segmented from FKP shown in Fig. 1.
in a localized way, without much redundancy as only the concerned fingers back surface is captured[8][9][10][11]. Band limited phase only correlation function is proposed in [11] by them which give EER in the range of 5.5% to 0.31%. In [9] they have proposed a local-global feature fusion for FKP verification; Local features are extracted using a bank of Gabor filters convolved with FKP ROI and global features are taken from band limited phase only correlation function. All of the approaches use the segmented FKP ROI, this is achieved by ROI segmentation (or Extraction [11]). In next section we discuss the existing scheme.

III. EXISTING TECHNIQUE FOR ROI EXTRACTION

The segmentation of ROI is actually developing a coordinate system and fitting it on to a Finger-Knuckle-Print. FKP image. With such a coordinate system, an ROI can be segmented from the captured image for reliable feature extraction. The ROI consist of region surrounding the phalangeal joint [11], this is a wrinkled part and has curvy lines, which contain information for FKP matching. Zang et al. have proposed a technique based on convex direction coding scheme [11]. This coding scheme is applied on an edge map generated from canny edge detection of input finger then they find the sum of values in a defined window (W) and the minimum magnitude gives the center of ROI (Y-axis location). The X-axis is taken as bottom-line of finger. Using this scheme they have separated a 220X110 Pixels size ROI for all the images in PolyU FKP database [7]. In this paper we use another approach for FKP segmentation, which uses Gradient field based parameters for fitting Co-ordinate system to the finger knuckle print.

IV. GRADIENT & COHERENCE CALCULATION

The proposed technique uses combination of two features derived from the gradient field of the FKP image. We use the direction of gradient field (Orientation)[16][17] and coherence that gives the strength of the averaged gradient in the distribution of local gradient vectors [18] to find out the location of phalangeal joint of the Finger-Knuckle, which will be the central part of ROI. In [16] authors have used this technique to detect the core point (reference point for correlation based fingerprint verification) of a fingerprint.

A. Gradient Definition

A gradient indicates gradual change of grey level [16]. The gradient direction is shown by arrows. The ridge is perpendicular to the gradient. The FKP image is divided in to W*W blocks. For Each block we estimate the gradient angle θ, also called as Orientation field Angle. This gives the orientation field of the finger-knuckle-print.

B. Gradient Calculation

We use gradient operator like 3*3 Sobel operator or another choice is to use a complex Marr-Hilderth operator. In this paper we have calculated gradient using a 3*3 Sobel mask for horizontal and vertical gradient calculation. The ridges may have two edges in a selected block, and hence

the calculated gradient vectors at both sides of ridge are opposite to each other, the opposite gradients at both sides of a ridge are likely to cancel each other. To solve this problem we use a method used in [17][18], involves doubling the gradient angles before the averaging. This method involves calculation of squared gradient. The gradient vectors can be denoted as $[g_x, g_y]^T$. Because of the doubling process the gradient angle ($\phi + \pi$) becomes ($2\phi + 2\pi$). Practically $2\phi$ is the angle of squared gradient vectors $[g_{sx}, g_{sy}]^T$ that has the following relation with $[g_x, g_y]^T$, hence we can write using trigonometric identities [18].

$$
\begin{align*}
\begin{bmatrix} g_{sx} \\ g_{sy} \end{bmatrix} &= \begin{bmatrix} g_x^2 \cos 2\phi \\ g_x^2 \sin 2\phi \\ g_y^2 (2 \sin \phi \cos \phi) \end{bmatrix} = \begin{bmatrix} g_x^2 \\ 2g_x g_y \\ g_y^2 \end{bmatrix} \\
\end{align*}
$$

(1)

The averaged squared gradients $[\frac{g_{sx}}{w}, \frac{g_{sy}}{w}]$ in a block of size W*W can therefore be calculated by

$$
\begin{align*}
\frac{g_{sx}}{w} &= \frac{\sum_{i=1}^{w} g_{sx}(i)}{w} \\
\frac{g_{sy}}{w} &= \frac{\sum_{i=1}^{w} g_{sy}(i)}{w}
\end{align*}
$$

(2)

C. Orientation & Coherence Calculation

We divide the input FKP image into equal size blocks of W X W pixels, and average over each block independently. The direction of orientation field is calculated as follows

$$
\theta_w = \frac{1}{2} \tan^{-1} \left( \frac{\sum_{i=1}^{w} \sum_{j=1}^{w} 2g_x(i, j)g_y(i, j)}{\sum_{i=1}^{w} \sum_{j=1}^{w} (g_{sx}(i, j))^2 + (g_{sy}(i, j))^2} \right) + \frac{\pi}{2}
$$

(3)

The desired range of $\theta_w$ is between $[0, \pi]$. This is perpendicular to gradient direction and gives direction of ridge in that block. In order to measure the strength of gradient field we also calculate one more parameter called coherence [17][18], which is given by Equation 4.

$$
Coh_w = \frac{\left| \sum_{i=1}^{w} \sum_{j=1}^{w} (g_{sx}(i, j)g_{sy}(i, j)) \right|}{\sum_{i=1}^{w} \sum_{j=1}^{w} |g_{sx}(i, j)||g_{sy}(i, j)|}
$$

(4)

One very important point to be noted is that the region which contains wrinkles have directional gradient field and hence the area surrounding phalangeal joint has orientation field in a loop pattern. Another thing is that the area which has absence of strong gradient (or Wrinkles) has low coherence. These facts are highlighted in Fig. 3. Finger-knuckle and the overlaid Gradient Orientation Field are shown in Fig. 3(a) & 3(b). Fig. 3(c) Shows corresponding Coherence map, Red colour indicates high coherence region whereas shades of green, blue and black shows the decreasing level of coherence. The area of phalangeal joint is highlighted in a square. In the next section we discuss
how the above mentioned parameters are used to locate ROI.

Figure 3. Orientation Field & Coherence of FKP Image (a) Field overlayed on FKP image (b) Actual Plot of gradient orientation field (c) Coherence of FKP Image (Block size is 16X16Pixels)

V. PROPOSED TECHNIQUE

We have discussed the Gradient orientation field and the coherence in the previous section. As we can see from Fig. 3(a) & (b) the field surrounding phalangeal joint of Finger-Knuckle is like a loop. We find cosine of local angular difference in an M X M size neighborhood. This is given by,

\[
S = \sum_{i} \sum_{j} \cos(Orientation[cx, cy] - orientation[i, j])
\]  \hspace{1cm} (5)

Figure 4. Typical Orientation (a) Normal Region (b) Surrounding phalangeal joint of Finger-Knuckle

We have considered a neighbourhood of 7X7 blocks, in case of Fig. 4(a) the sum will be high as the difference of angle with surrounding is low, in case of Fig. 4(b) as the difference is high, the sum will be low. The phalangeal joint of Finger-Knuckle this value will be low. This will give a map like Fig. 5. This gives the possible location for the center of ROI.

As we can see in the Fig. 5, it does not give the final location, we make use of the coherence to finalize. We normalize both the arrays (Coherence & Cosine Sum) and generate final feature map by adding these two feature arrays which will be used to give center of ROI. We find the vertical & horizontal projections of the ROI feature map shown in Fig. 6(a), the vertical projection is shown in Fig. 6(b). The center of ROI is taken as the intersection of minimum point on the ROI projection (both Horizontal and vertical).

The final ROI is taken as 256X128 Pixels size image around the ROI center thus found. This size is not fixed and can be varied. In the next section we discuss the experimentation setup and results.
Proposed technique is tested on the Hong Kong Polytechnic University Finger-Knuckle-Print database [7], this database comes with the ROI images, and we have compared our results with the given ROI images. The program is written in Microsoft Visual C# 2005, tested on AMD Athlon 64FX, 1.8GHz Processor, Windows XP SP3 Operating System (32 Bit). The results are shown in Fig. 7 for one finger. Fig. 7 (a) indicates input and fig 7 (b) indicate output, Fig 7(c) is the output given by previous technique given by Zang [11]. The testing summary is given in Table I.

TABLE I. TESTING SUMMARY

<table>
<thead>
<tr>
<th>Total Images Tested</th>
<th>Successful</th>
<th>Failure</th>
<th>Average testing time per Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>502</td>
<td>483</td>
<td>19</td>
<td>110 milliseconds</td>
</tr>
</tbody>
</table>

Proposed technique was tested for 502 random images from the database. The success rate of proposed technique is 96.21%. After analysis of the failed test it was found that the reasons for the failure were improper Placement of finger & high illumination causing the suppression of finger details. Some such cases are shown below.

![Failed Tests](image)

Figure 8. Failed Tests (a) & (b) Improper Placement of Fingers (c) High Illumination of Finger.

VI. CONCLUSION

In this paper we have proposed a new technique to segment the region of interest of Finger-Knuckle-Print images. This technique can be used in the preprocessing step for implementing FKP verification. The technique is fast and takes average 110 ms to segment the ROI. We have used Gradient Orientation and field strength to detect the center of ROI, the accuracy given by proposed technique is 96.21%, this method is another viable practical approach to real time FKP ROI segmentation.

ACKNOWLEDGMENT

Authors are very thankful to L. Zhang, Assistant Professor, Biometric Research Centre (UGC/CRC), The Hong Kong Polytechnic University, for providing the Finger-Knuckle-Print database. This database has been a key resource for this research.

REFERENCES