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A NEW ALGORITHM TO COMPUTE DIRECTIONAL FIELDS AND SINGULAR POINTS FROM A FINGERPRINT

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ABSTRACT

This paper proposes a new algorithm for computing directional fields and singular points from a fingerprint. Directional field (DF) is defined as the local orientation of the ridge valley structures and singular points (SPs) are the points in a fingerprint where the DF is discontinuous. DF and SPs can be used in fingerprint verification system. This paper shows the way of deriving DF from the gradients by performing some averaging operation on the gradients involving some pixels in some neighborhood. Various methods have been used to establish the DF from a fingerprint. These approaches do not provide as much accuracy as gradient based methods, mainly because of the limited number of possible orientations. This paper also shows SPs extraction method that uses segmentation algorithm. This segmentation algorithm will be capable of detecting low quality areas in a fingerprint. It is capable of high resolution SPs extraction and does not need to use heuristic post processing. We have evaluated the performance of the algorithm by experiments on a live scanned database. Experimental results show that this algorithm offers simple processing but presents more accurate results than traditional methods belong to.

1. INTRODUCTION

Fingerprints are composed of ridges, the elevated lines of flesh [1,2,3] that make up the various patterns on the print, separated by valleys as shown in Fig. 1(a). It is possible to identify two labels of details in a fingerprint. These are The DFs and the minutiae. The DF is, in principle, perpendicular to the gradients. However, the gradients are orientations at pixel scale, while the DF describes the orientation of the ridge valley structures, which is a much coarser scale as shown in Fig. 1(b). The minutiae provide the details of the ridge valley structures, like ridge endings and bifurcations. Minutiae used for fingerprint matching, which is a one to one comparison of two fingerprints [4]. This paper focuses on the directional field of fingerprints and matters directly related to the DF.

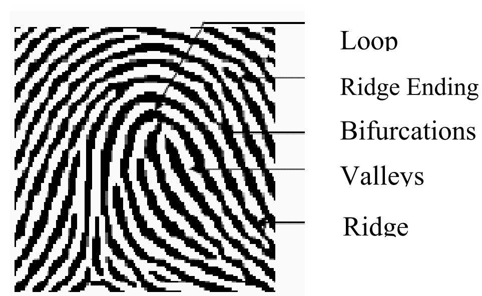


Fig. 1(a) Typical Fingerprint

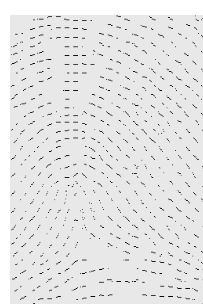


Fig. 1(b) Directional field

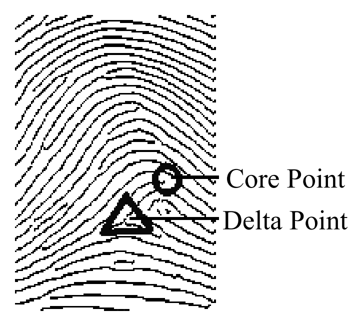


Fig. 1(c) Extracted SPs

In the DF, singular points can be identified. Henry [5] defined two types of SPs, in terms of ridge valley structures. The core is the top most point of the inner most curving ridge and a delta is the center of triangular regions where three different direction flows meet. These two types of singular points found in a fingerprint are shown in Fig. 1(c).

There are various methods that have been used to estimate the DF from a fingerprint. They include match filter approaches, methods based on the high frequency power in three dimensional spectral estimation methods and micro patterns that can be considered binary gradients. These methods do not provide as much accuracy as gradient based methods, mainly because of the limited number of possible orientations. These are especially important when using the DF for task like tracing flow lines.

This paper proposes a method to derive DF from the gradients by performing some averaging operation on the gradients, involving pixels in some neighborhood and also proposes an estimation method for the orientation of SPs. The proposed SPs extraction method offers consistent binary decisions [1] that can be implemented very easily. The method computes for each individual pixel whether it is a SP, and is therefore capable of detecting SPs that are located only a few pixels apart.

The most common use of SPs is registration, which means that they are used as references to line up two fingerprints. Another example of their use is classification of fingerprints in the Henry classes [5].

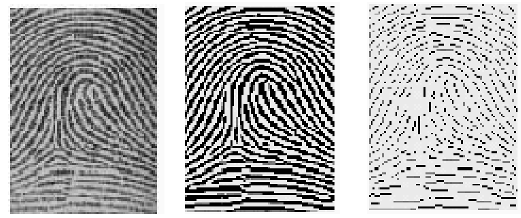
2. PRE-PROCESSING

Before applying the proposed method for estimating DFs and SPs, some pre processing were made that are outlined shortly in the following paragraphs:

2.1 Image Filtering

Every sensor has its own characteristics, but in general the quality of the acquired fingerprint image is rather poor. This is partly due to non-uniform contact between the finger and the sensor surface, which causes breaks in ridges and bridges between them. Overall grey scale intensity variations, poor contrast and noisy background is also frequently encountered issue. Furthermore, age and profession, and other environmental differences affect the quality of a person's fingerprint. For example, elderly people usually lack well-defined ridges and valleys, thus yielding a poor quality image from the sensor. Another problem to be considered is the oil and dirt that is left behind on the sensor surface from previous fingerprints, further degrading print quality. All these problems must be dealt with before feature extraction [3,4].

For these purposes the image is enhanced to fill "holes" and to increase the contrast in the, many times pretty rough, greyscale fingerprint image from the sensor. That is, making the non-continuous ridges and valleys of the fingerprint continuous, extracting the highly interesting foreground from the noisy and irrelevant background.



(a) (b) (c)

Fig. 2 (a) Input image, (b) background filter, (c) Morphology analysis

Fig. 2(a) is taken as input image. Fig. 2(b) is achieved after filtering the Input image of a fingerprint (as shown in Fig. 2(a)) and the thick ridgelines found after filtering are made thinner and noise free as shown in Fig. 2(c).

2.2 Image Processing

In this stage, black color that constitute the ridge lines and white color that separates those ridge lines are identified for each pixel. RGB (0,0,0) is stored in corresponding coordinates for black color and RGB (255,255,255) is stored for white color. The algorithm for image processing is as follows:

1. Take input image of a defined WIDTH×HEIGHT. Calculate each pixel's RGB values that contain three numerical values ranging from 0 to 255.

2. If all of three returned values of RGB function are equal to 0, then put the pixel of BLACK colour [RGB (0,0,0)] to the Corresponding Coordinates

Else if

Put the pixel of WHITE colour [RGB (255,255,255)] to the Corresponding Coordinates.

Thus a matrix array is formed where each element store 0 or 1 according to the above assumptions.

3. DIRECTIONAL FIELD ESTIMATION

We fragmented the line filled image in a number of small blocks. Each block dimension contains 11 × 11 pixels so that each ridge line is separated from each other. In each 11 × 11 pixel box, we calculated the starting and ending points of the ridge line and then drew a straight line connecting these two points that gives us very accurate DFs.

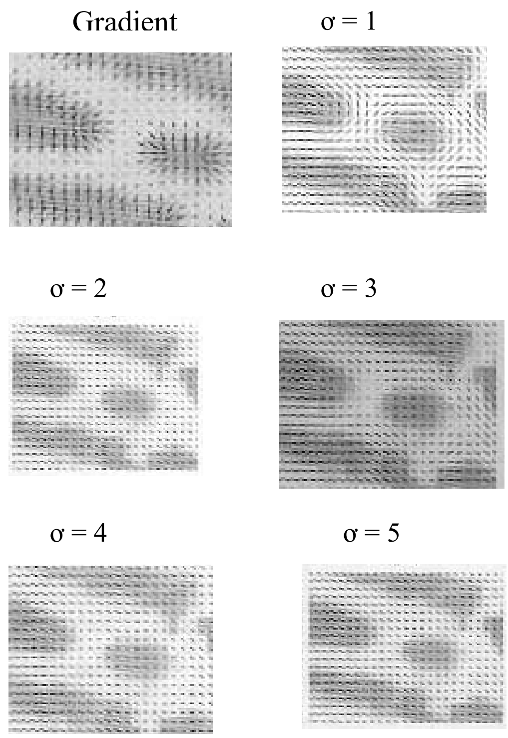


Fig. 3 Gradients and DFs for various values of σ

We used a fixed size Gaussian window (σ=5) to minimize false singular points in the DF [6]. In fig 6, the DF is shown in a small segment of 25 × 20 pixels. This segment contains broken ridge lines that are almost horizontal. In this experiment σ is chosen in the range from 1 to 5. It is found form the Fig. 3 that the DF is very erratic for small values of σ. For higher values of σ, the DF becomes more uniform and the lines get longer, indicating higher coherence values.

4. SINGULAR POINTS EXTRACTION

If the DF is not averaged sufficiently, this may results in many false singular points. A DF that has not been averaged at all, may contain as many as 100 spurious core delta pairs, especially in noisy reasons like the borders of the image [7]. When averaging the DF, these pairs both merge and disappear or float off the border of the image [7].

In fingerprint recognition, only the SPs at the ridge valley scale are valid SPs. This means that the SPs have to be extracted from a DF that is estimated at this scale [8]. The SPs extraction method will only provide satisfactory results if the scale is chosen well by sufficient averaging, since a fingerprint never contains more than two "core-delta" pairs. This might provide a check to see whether the right scale has been reached. From the experiments, it was found that the value of σ is optimal if it is 6. We found delta and core by applying Poincare index method [9]. Here, we got delta when 38< ∝ >=40 or ∝= 180 and core was found when 44<= ∝ >=46, where ∝ is the algebraic sum of the angular differences of the DFs. The algorithm for SPs extraction is shown as follows:

```
SPs Extraction ()

Asum ← Sum of angle difference
Diff ←Angle difference

If the pixel is WHITE  then
          Angle ← 0
Else
          Difference_of_X ← X2 - X1
         Difference_of_Y ←  Y2 - Y1

 If Difference_of_Y = 0 then
          Angle ←  0

 ElseIf Difference_of_X =0 then
  Angle ← 90
 Else
Difference←Difference_of_Y-Difference_of_X
Angle ← Inverse tangent of Difference

If Difference of_X> 0 Then
  Angle = 180 – Angle in degree

Temp (Count) ← Absolute value of angle
Count ← Count + 1

For K = 0 To 10
  Diff ← Temp (K) - Temp (K + 1)
 Asum ←  Diff + Asum
    If Aasum >= 46 And Asum <=44 Then
     Core found
     Else do nothing
  End If

  If Asum > 39 And Asum <= 40 or Asum = 180
Then
       Delta found
 Else
      Do nothing
 End If
 Next
```

Thus the singular points are extracted from DFs.

5. EXPERIMENTAL RESULTS

Live scanned fingerprints were collected from FVC2000 databases [10]. After applying the proposed method, DFs were estimated from those fingerprints. Then SPs were computed from the calculated DFs as shown in Table 1 and Table 2.

Table 1: Experimental results for core points

SAMPLE	X_1	Y_1	X_2	Y_2
Image1	10	77	×	×
Image2	44	241	×	×
Image3	160	40	×	×

Table 1 shows that we have detected one core point for Image1 (sample fingerprint) at the point (10,77) where 10 is the distance along X axis and 77 is the distance along Y axis. In Image2 only one core was found at the point (44,241). Image3 also contains a core that was extracted at the point (160,40).

Table 2: Experimental results for delta points

SAMPLE	X_1	Y_1	X_2	Y_2
Image1	121	285	×	×
Image2	66	318	×	×
Image3	128	28	×	×

Table 2 shows that we have detected one delta point for Image1 at the point (121,285) where 121 is the distance along X axis and 185 is the distance along Y axis. In Image2, only one delta was found at the point (66,318). Image3 also contains a delta that was extracted at the point (128,28).

6. CONCLUSIONS

In this paper a new algorithm is proposed to compute DFs and SPs of a fingerprint. This method provides accurate result, offers a different view and an increase of insight on the problem of estimating an average DF. It is pointed out that the methods that are presented in this paper can be used either to estimate a high-resolution DF or to improve the accuracy of block DF. Application of the proposed method to fingerprints shows high resolution and accuracy, compared to the traditional block wise processing schemes. It is shown that our method is capable of correctly segmenting very noisy fingerprints.

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