FINGERPRINT ENHANCEMENT BASED ON THE DIRECTIONAL FILTER BANK

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ABSTRACT

Fingerprints have been used as a means to identify individuals uniquely for a very long time in various situations. In order to achieve robust performance of an automatic fingerprint identification/verification system, it is essential to be associated with a fingerprint enhancement algorithm in the minutiae extraction stage. We present a novel fingerprint enhancement system based on the directional filter bank. The directional filter bank is a maximally decimated filter bank with perfect reconstruction property that is able to decompose wedge-shape frequency components by using an 1-D filter prototype. By using the newly improved visualizable subbands in addition to the previous features of the directional filter bank, an efficient enhancement can be achieved in terms of both computation ad memory saving.

1. INTRODUCTION

Fingerprints have been used as a means to identify individuals uniquely for various purposes such as criminal identification, high security access control, credit card usage verification, and employee identification. The main reason for the popularity of fingerprints as a method of identification results from the fact that each fingerprint of a person is unique as well as easy to access. Some commonly used features are provided in Figure 1.

A system for feature extraction of a fingerprint image is shown in Figure 2. Enhancement in Figure 2 refers to accentuation, or sharpening of minutiae, in addition to reducing noise and undesirable discontinuities. This stage in the feature extraction plays an important role in many fingerprint applications. Note that the enhancement of a fingerprint image does not provide an aesthetically improved image. An enhanced image should retain as many minutiae as possible and suppress misleading patterns even if it would produce an aesthetically degraded image. Since the ridges that comprise the fingerprint are inherently directional, the proposed method based on a directional filter bank is well matched to the problem.

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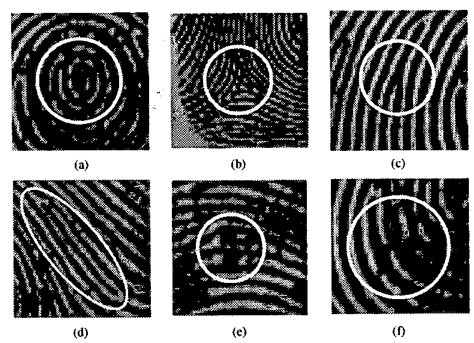

Fig. 1. Features of fingerprint images. (a) Core. (b) Delta.(c) Ridge bifurcation. (d) Ridge ending. (e) Enclosure. (f) Short ridge.

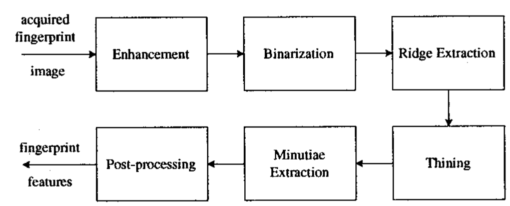

Fig. 2. A schematic block diagram of fingerprint feature extraction.

The system we introduce in this paper involves, as the first step, a directional decomposition [1] followed by enhancement processing, the details of which are described in Section 2. After the enhancement, segmentation is performed to separate the foreground and background. The ridges are then extracted from the gray-level foreground region and followed by a thinning operation that thins the

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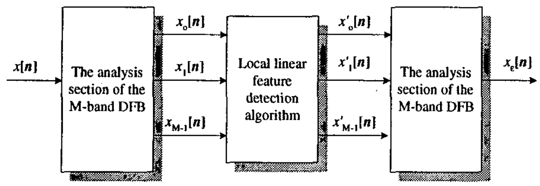

Fig. 5. A fingerprint enhancement system based on the new DFB.

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$$w_i[\mathbf{n}] = \begin{cases} 1 & \text{if and only if } e_i[\mathbf{n}] = \max_j\{e_j[\mathbf{n}]\}, \\ \frac{1}{2} & \text{if and only if } e_{i\pm1}[\mathbf{n}] = \max_j\{e_j[\mathbf{n}]\}, \\ 0 & \text{otherwise.} \end{cases} \quad (3)$$

Fig. 6. A fingerprint image.

Figure 6 provides an example of a fingerprint to be enhanced. An eight-band DFB is used for directional analysis, whose subband images are given in Figure 7. Note that there are some undesirable linear distortions, i.e. horizontal scratches in the fingerprint. These undesirable distortions are separable in the directional subband domain, as shown in the seventh subband image—Figure 7(g). The principle we exploit is that within the subband images, the undesirable distortions can be isolated spatially and removed.

Each of the subbands can be segmented by using soft-thresholding [4] to obtain a binary mask image, which can then be followed by a dilation operation [5]. This provides a way to isolate the fingerprint and distortion components spatially. As an illustration, Figure 8(b) shows the output of this thresholding and dilation process applied to the seventh subband in example decomposition. Here we see that six isolated spatial regions can be identified. The regions that contain distortion information need to be identified and removed.

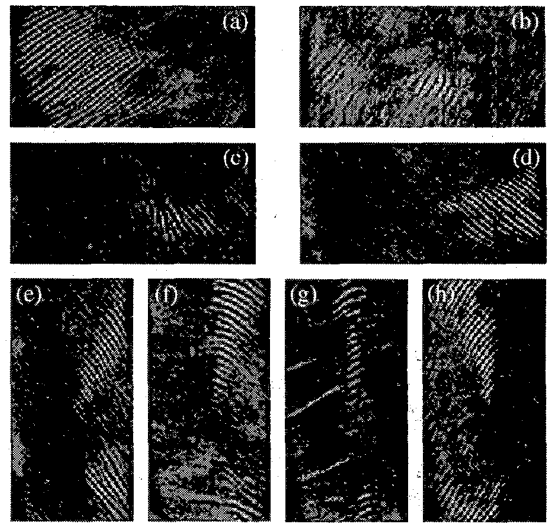
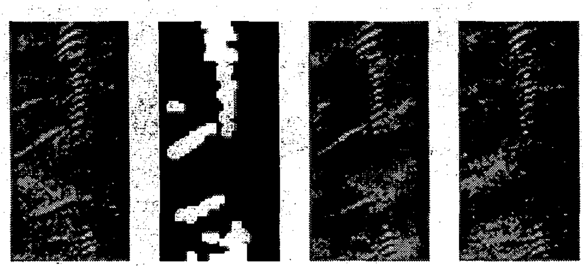


Fig. 7. Directionally decomposed fingerprint images by an eight-band DFB. The labeling is consistent with Figure 3.

To find the regions that contain the distortions, we can examine the projection characteristics along the primary axis of directionality. That is, the projection along the direction associated with the particular subband will reveal a highly vary (oscillating) characteristic for regions containing fingerprint information. However, for regions that contains scratches or other distortions of this type, the projection characteristics will have much less variation. Thus, the projection zero-crossings can be used as a simple measure to distinguish regions representing distortion from regions containing fingerprint information.

This notion is illustrated pictorially in Figure 9, which shows two segmented regions obtained from the thresholded and dilated subband image mask in Figure 8(b). The subband images in Figure 9 are obtained by overlaying the the six regions of the binary mask image individually on the seventh subband image shown in Figure 8(a). Next to each of these six subband images is the 1-D projection taking in the $\pi/16$ angular direction (which is the angular direction of the seventh subband). As can be seen, the zero-crossings of the projections associated with the scratches have a low zero-crossing count, while the opposite is true of the subbands containing fingerprint information.

Once the regions corresponding to distortion have been identified, their pixel values can be replaced with the values of their neighborhood pixels. This is illustrated by the subband image shown in Figure 8 (d). In this way we effectively neutralize the visible scratch discontinuities when the subband images are reconstructed. A reconstructed and enhanced fingerprint image is given in Figure 10(a). No-



(a) (b) (c) (d)

Fig. 8. Preprocessing for detection of undesirable isolated discontinuities. (a) The seventh subband image. (b) Segmented image after soft-thresholding. (c) The seventh subband image masked by the image of (b). (d) An enhanced image.

tice that the undesirable distortions have been greatly suppressed. That is, most of the holes in the ridges are now filled and the other important features are still preserved. The enhanced image in Figure 10(a) is then binarized (shown in (b)) and thinned (shown in (c)) using algorithms published previously in [6]. The enhanced representation in the binary thinned form can now be used for analysis and classification. The key to success for fingerprint classification is to preserve the important classification features that are extracted. These features which are shown in Figure 1 include core points, delta points, ridge bifurcations, ridge endings, enclosures, and short ridges. The new approach discussed in this paper tends to preserve these important features, while at the same time removing unwanted distortions.

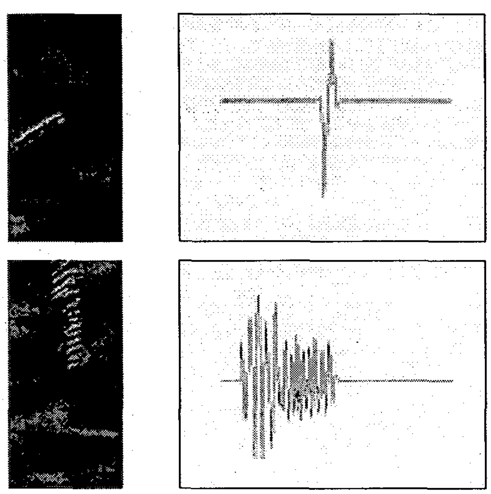


Fig. 9. Some segmented regions and their normalized projection at $\frac{\pi}{16}$ of Figure 8 (c).

(a) (b) (c)

Fig. 10. The enhanced fingerprint image based on the directional filter bank. (a) The enhanced fingerprint image. After (b) binarization and (c) thinning.

3. CONCLUSION

A fingerprint enhancement system based on the directional filter bank is proposed. Employing the improved structure, the system can be simpler than the previously proposed one. Using features of each of the subbands, the system neutralizes the regions where undesirable distortions exist. Robust enhancement systems based on the directional filter banks for various environments are currently under development.

4. REFERENCES

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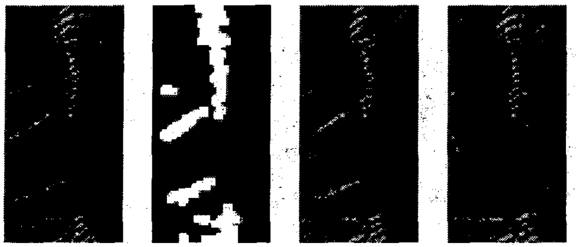

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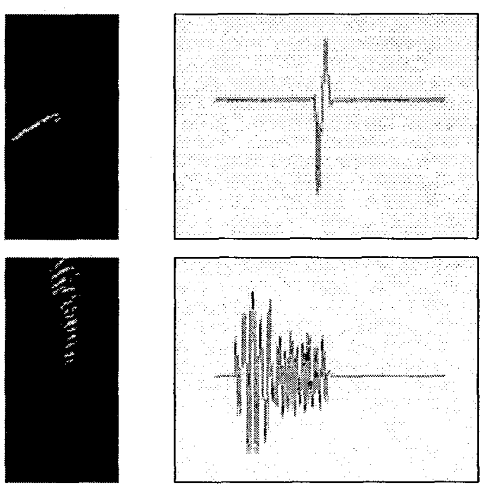

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