fingerprint recognition, directional image, orientation field

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THE PIXEL ALIGNMENT BASED ALGORITHM FOR CONTINUOUS ORIENTATION FIELD ESTIMATION

This paper presents a new estimation method of fingerprint orientation field. An accurate estimation of fingerprint orientation fields is an essential step in automatic fingerprint recognition systems (AFIS). Most popular, gradient–based method is very sensitive to noise (image quality). Proposed algorithm is a modification of, more resistant to noise, mask-based method, which provides orientation limited to discrete values. This modification is based on aggregation of pixel values differentiation and was used to more precise estimation of magnitude of orientation vectors. This approach allows to obtain a continuous values of orientation field still maintaining robust to noise.

1. INTRODUCTION

Among all biometric techniques, automatic fingerprint based systems have been receiving increasingly more attention. Fingerprints based system is considered as one of the most reliable and easy to use biometric system for human identification or verification. During the last years its performance has reached a high level. Nevertheless, it is still not satisfying for fingerprints images with poor quality [1]. Therefore image enhancement has become a necessary and common step before feature extraction in the AFIS.

Generally, fingerprints contain two kinds of features: global features, such as a ridge pattern orientation and frequency, and local features like minutia or singular points (core and delta). As a global feature, orientation field describes local orientation of the ridge–valley structure in each point of fingerprint image (Fig. 1).

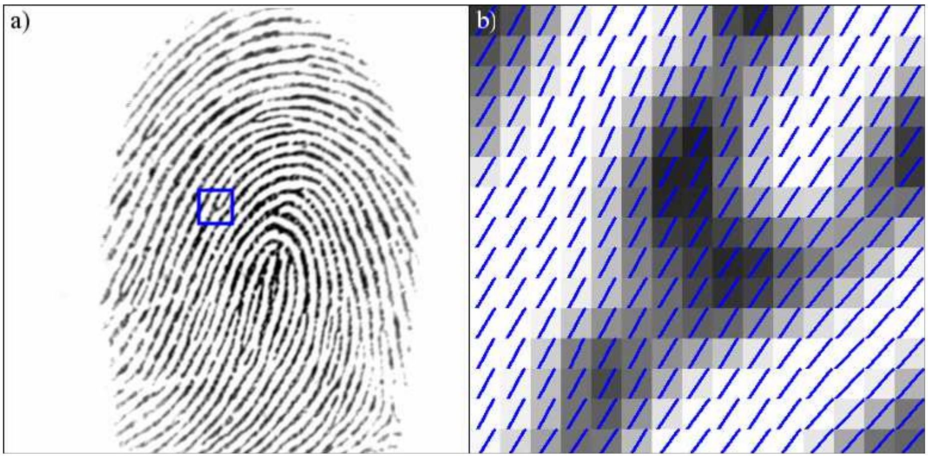

Fig. 1 a) Original fingerprint image, b) magnified area with marked dominant orientation of each pixel.

Orientation field has been widely used for fingerprint image enhancement [2,3], singular points detection[4,5,6] and classification [7, 8].

Generally, there are two categories of methods to compute the orientation field (also called directional field or directional image): pixel–alignment based [7,9,10,11] and gradient based methods [2,5,12,13,14]. Typically, the pixel–alignment-based methods compute the differentiation (fluctuation) of neighboring pixels values in a fixed number of reference orientations (Fig. 2b). The most popular gradient

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based method is presented by M. Kass and A. Witkin [13] least squares contour alignment method. The most important advantage of this algorithm is the fact, that the obtained values are continuous (Fig. 2c). Most advanced orientation field enhancement method is model–based method [18, 19], which rely on the global regularity of orientation values around the singular points. However, forensic images of latent fingerprints not always contain those singular points.

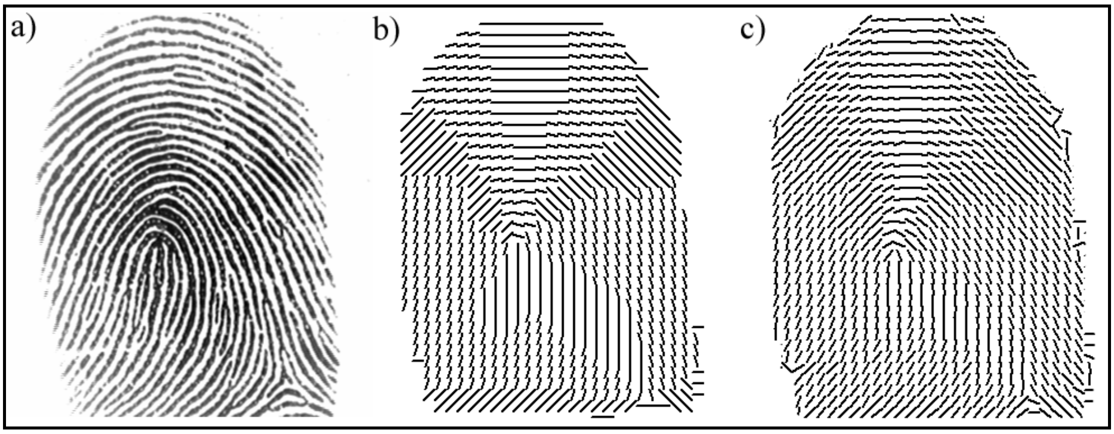

Fig. 2. a) Original fingerprint image. Orientation field estimated by: b) pixel-alignment method c) gradient based method.

2. ESTIMATION OF ORIENTED DIFFERENTIATIONS

In presented method, the orientation field is computed by mask of eight oriented differentiation of pixel values which are used as magnitude of orientation vectors. Structure of this 9×9 mask (Fig. 3) was presented in [15] and was specially developed to obtain dominant direction of fingerprint ridge–valley structure. Estimated values were limited to fixed number of eight discrete values, therefore this modification use this mask only to compute eight differentiation of pixel values.

In the first stage, the mean values of five pixels in eight directions are computed:

$$S_i(x,y)=\frac{\sum_{j=1}^{5} p_j^i}{5},\quad i=0,1,...,7 \tag{1}$$

where:

- S_i – the means of pixel values in eight direction,
- p_j^i – the pixel values in one from *i* directions,
- i – the discrete direction value (0,…,7), respectively from 0° to 157,5°, with 22,5° step.

In next stage, compute the differentiation (fluctuation) of neighboring pixels values, in each direction, by:

$$Df_i(x,y)=\sum_{j=1}^{5}\left|S_i(x,y)-p_j^i\right|,\quad i=0,1,...,7 \tag{2}$$

The orientation of lowest fluctuation of gray values is expected to be the reference orientation of central pixel.

Due to the presence of some unreliable elements, resulting from heavy noise, corrupted ridge and furrow structures, minutiae and low gray value contrast, estimated differentiation values may not always be correct. The orientation smoothing stage is expected to reduce the noise and compute a reliable value.

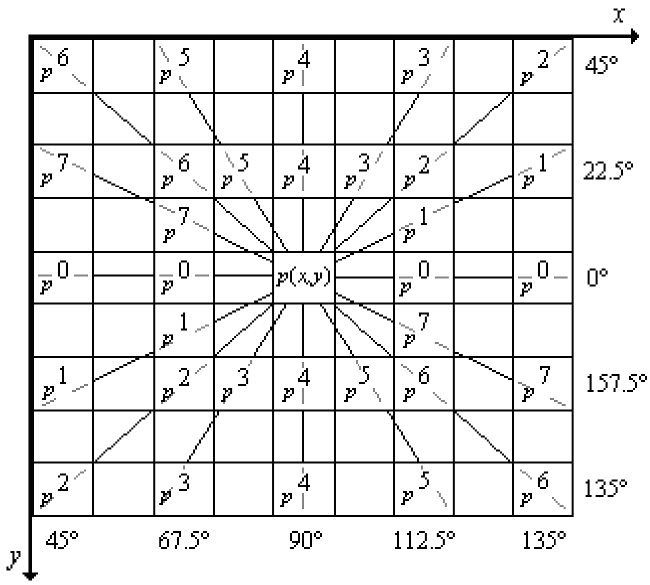

Fig. 3. The 9×9 mask to compute the differentiation of the pixel values.

The averaging is computed for each pixel in 13×13 window, separately in each direction values, respectively:

$$Ad_i(x,y) = \sum_{u=x-\frac{W}{2}}^{x+\frac{W}{2}} \sum_{v=y-\frac{W}{2}}^{y+\frac{W}{2}} Df_i(u,v), \quad i = 0,1,...,7 \tag{3}$$

where: $W = 13$.

3. ORIENTATION FIELD ESTIMATION

Since the orientation of smallest value, from all eight oriented averaged differentiation values, is expected to be the most close to the orientation of that pixel, these values can be used as magnitude of orientation vectors.

Experimental results show that the smallest value of the differentiation is changes in the range of 100–500. The greatest value (which is orthogonal to the orientation) has range of changeability 7000–15000. For this reason, the normalization step is necessary:

$$Na_i(x,y) = \frac{Ad_i}{Ad_{\min}}, \quad i = 0,1,...,7 \tag{4}$$

where: $Ad_{\min} = \min\{Ad_0, Ad_1, ..., Ad_7\}$ is the smallest value from all eight averaged values (3).

The orientation field estimation is separately computed for two ranges of minimal orientation values respectively:

1. If direction of smallest value is between -45° and 45° $(2 \geq i_{\min} > 6)$:

$$Vd_1(x,y) = \sum_{i=0}^{7} \frac{(22,5 i\pi - z)}{180 Na_i(x,y)} \tag{5}$$

where: if $i_{\min} < 2$ then $z = 0$, otherwise $z = \pi$.

2. If direction of smallest value is between 45° and 135° $(2 < i_{\min} \le 6)$:

$$Vd_2(x,y) = \sum_{i=0}^{7} \frac{(22,5 i\pi)}{180 Na_i(x,y)} \tag{6}$$

where: $i_{\min}$ is direction (argument) of the smallest value $Ad_{\min}$.

Finally orientation field is estimated by:

$$\theta(x,y) = \frac{Vd_1(x,y) + Vd_2(x,y)}{\sum_{i=0}^{7} \frac{1}{Na_i(x,y)}} \tag{7}$$

4. EXPERIMENTAL RESULTS

The proposed algorithm had been applied on fingerprint images database, which contains 960 fingerprint images (in 500dpi resolution) from 120 fingers, with 8 images from each finger. Fingerprint images in database were selected from NIST Special Database, FVC database samples, and captured with a live–scanner. Fig. 4 for comparison shows two examples of orientation estimation results of fingerprint images, selected from this database.

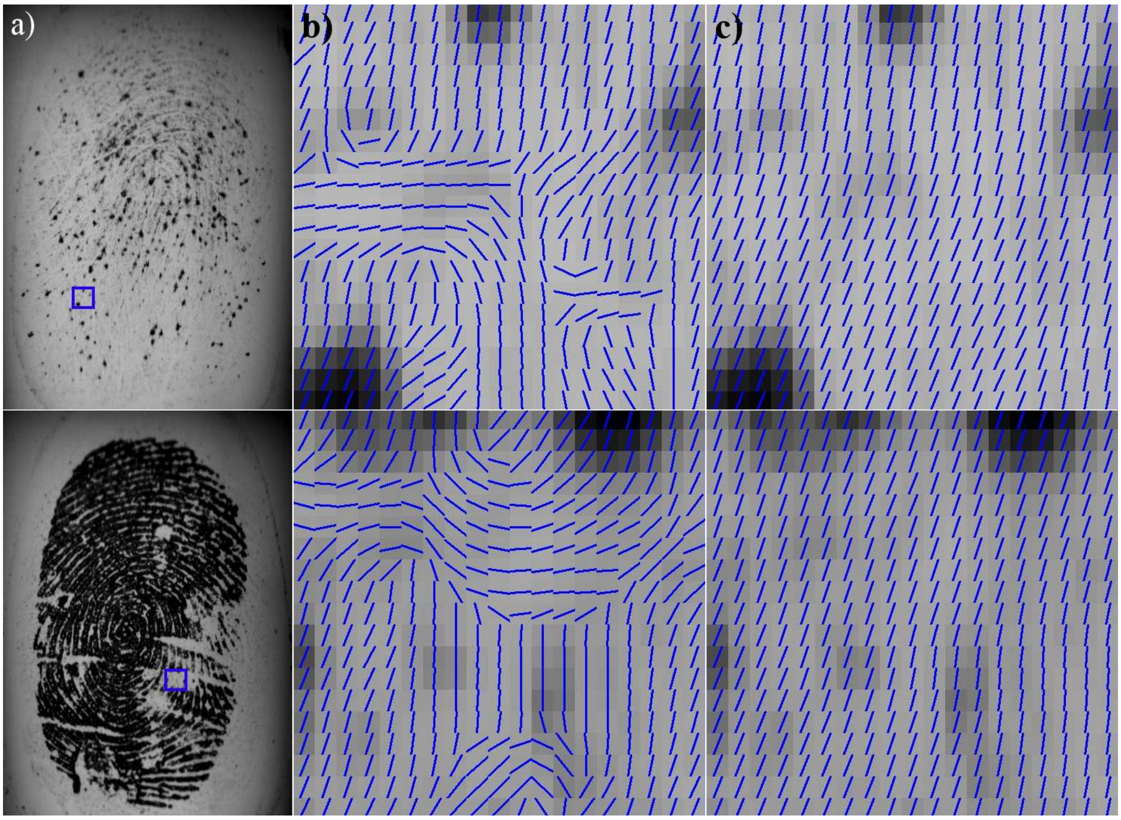

Fig. 4. a) Original low quality fingerprint images. Magnified areas with orientation values marked: b) estimated by gradient–based method [17], c) estimated by the presented method.

In order to obtain the performance characteristics such as EER, on the first testing data a fingerprint image enhancement algorithm [16] was evaluated. In the next step the NISTs NFIS2 open source software was used for feature extraction and matching [17]. Proposed algorithm results in a notable reduction of Equal Error Rate, as shown in DET Fig. 5.

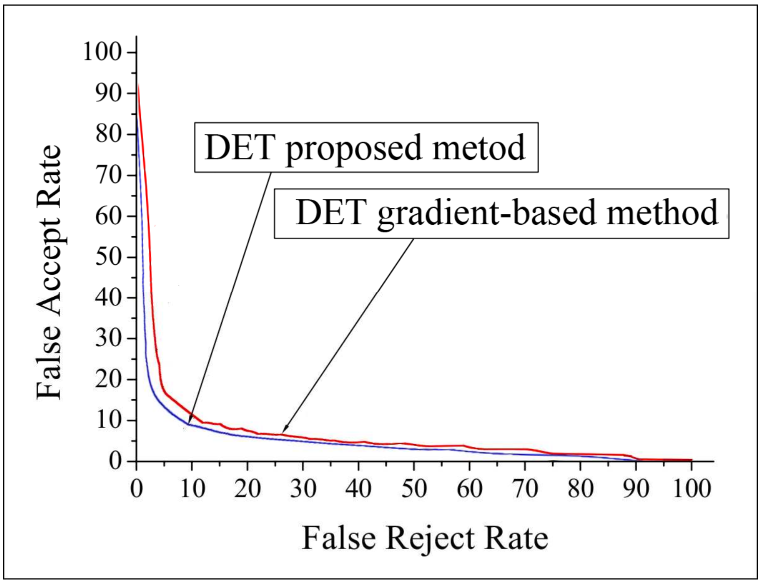

Fig. 5. DET curves, orientation estimated by: gradient-based method [17] and proposed method.

When there is a trade–off of error types, a single performance number is inadequate to represent the capabilities of a system. Such a system has many operating points, and is best represented by a performance curve. The ROC curves (Receiver Operating Characteristic) traditionally are used for this purpose. Generally, false rate is plotted on the horizontal axis, while the correct detection rate is plotted on the vertical axis. The DET curves (Detection Error Trade–off) give the alternative solution. In the DET curve, we can plot error rates on both axes, giving uniform treatment to both types of error, and use a scale for both axes which spreads out the plot, better distinguishes performing system and usually produces plots that are close to linear.

5. CONCLUSIONS

This paper presents an improved technique for orientation field estimation. It can be concluded from evaluated experiments, that by using proposed algorithm, the estimated results are accurate and robust to noise.

Further work will consider the application of this method, combined with gradient-based method, in order to reduce the computational costs.

BIBLIOGRAPHY

[1] JAIN A.K., BOLLE R.,PANKANTI S., Biometrics: Personal Identification in Networked Society. Kluwer, New York, 1999.

[2] HONG L., JAIN A. K., WAN Y., Fingerprint Image Enhancement: Algorithm and Performance Evaluation. IEEE Trans. on Pattern Analysis and Machine Intelligence, Vol. 20, No. 8, 1998, pp. 777–789.

[3] CHIKKERUR S., CARTWRIGHT A. N., GOVINDARAJU V., Fingerprint enhancement using STFT analysis. Pattern Recogn. Vol. 40, No. 1, 2007, pp.198–211.

[4] LIU M., JIANG X., KOT A. C.: Fingerprint reference–point detection. EURASIP J. Appl. Signal Process. 2005, pp.498–509.

[5] BAZEN A. M. GEREZ S. H., Systematic Methods for the Computation of the Directional Fields and Singular Points of Fingerprints. IEEE Trans. Pattern Anal. Mach. Intell. Vol. 24, No. 7, 2002, pp. 905–919.

[6] WRÓBEL K. DOROZ R., New Method For Finding a Reference Point in Fingerprint Images With the Use Of The IPAN99 Algorithm. Journal of Medical Informatics & Technologies. Vol. 13, 2009, pp.59–64.

[7] HONG L., JAIN A. K., PRABHAKAR S., A Multi–channel Approach to Fingerprint Classification. IEEE Trans. Pattern Anal. Mach. Intell. Vol. 21, No. 4, 1999, pp.348–359.

[8] COSTA S. M., FERNANDEZ F. J., OLIVEIRA J. M., A New Paradigm on Fingerprint Classification using Directional Image. SIBGRAPI, 2002, pp. 405.

[9] JAIN A. K., KARU K., Fingerprint classification. Pattern Recognition, Vol. 29, No. 3, pp. 38–44, 1996.

[10] HALICI U., ONGUN G., Fingerprint classification through self–organizing feature maps modified to treat uncertainties. Proc. of the IEEE, Vol. 84, No. 10, 1996, pp.1497–1512.

[11] HONG L., JAIN A. K., PANKANTI S., PRABHAKAR S., Filterbank–based fingerprint matching. IEEE Trans. Image Processing, Vol. 9, No. 5, 2000, pp.846–859.

[12] MAIO D., MALTONI D., Direct gray–scale minutiae detection in fingerprints. IEEE Trans. Pattern Anal. Mach. Intell.Vol. 19, No.1, 1997, pp.27–45.

[13] KASS M., WITKIN A., Analyzing Orientated Pattern. Computer Vision, Graphics and Image Processing, Vol. 37, 1987, pp.362–397.

[14] HONG L., JAIN A. K., On–line Fingerprint Verification. IEEE Trans. Pattern Anal. and Mach. Intell. Vol.19, No.4, 1997, pp.302–314.

[15] PORWIK P., WIĘCŁAW Ł., A new approach to reference point location in fingerprint recognition. IEICE Int. Journal Electronics Express. Japan. Vol. 1, No. 18, 2004, pp. 575–581.

[16] PORWIK P., WIĘCŁAW Ł., The New Efficient Method of Fingerprint Image Enhancement. Int. Journal of Biometrics. Inderscience Publisher, Vol. 1, 2008, No.1, pp.36–46.

[17] http://fingerprint.nist.gov

[18] ZHOU J., GU J., A model–based method for the computation of fingerprints' orientation field. IEEE Transactions on Image Processing, Vol. 13, No. 6, 2004, pp. 821–835.

[19] DASS S. C., Markov random field models for directional field and singularity extraction in fingerprint images. IEEE Transactions on Image Processing, Vol. 13, No. 10, 2004, pp. 1358–1367.