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A new approach to reference point location in fingerprint recognition

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Abstract: Fingerprint matching is one of the most important problems in Fingerprint Identification System (AFIS). In this paper a new method of the reference point alignment has been presented. A new approach of reference point localization is based on so-called identification masks which have been composed on the basis of analysis of biometric characteristic of human finger. Construction of such masks has been presented.

Experiments show that our approach locates a unique reference point with high accuracy for all types of fingerprints. Generally, fingerprint matching consists with three steps: core (reference) point detection, filter the image using a bank Gabor filters, and comparison with imprint pattern. It seems, that today, the Gabor filtering gives the best results in fingerprint recognition. The proposed method was evaluated and tested on various fingerprint images, included in the FVC2000 fingerprint database. Performed results with representative investigations have been compared.

Keywords: Fingerprint recognition, reference point determination

Classification: Science and engineering for electronics

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1 Introduction

The fingerprints are extremely complex. For fingerprint identification, the most technically critical is detection of a reliable reference point. To locate a unique reference point for all types of fingerprints, we define the reference point as the point with maximum curvature on the convex ridge, which is usually located in the central fingerprint area [5]. In general, a analyzed fingerprint is a well-defined orientation field, which has to compared with pattern. In most cases the reference point detection methods operate on the orientation field of fingerprint. The Poincare index analysis is well known method described in [5]. Unfortunately, this method is sensitive to noise of orientation field. Very efficient method proposed in [2] is based on multiresolution analysis, but this method is sensitive to the fingerprint rotation. Additionally, a fingerprint may be corrupted by noise due to finger pressure variation, skin properties etc. during image capture. Fingerprint enhancement is used to recover the topology structure of ridges and valleys from the noisy image. Most of the fingerprint enhancement algorithms based on the estimation of the orientation field [1]. In presented method, the orientation field, with some additional modifications, to reference point indication has been exploited. In our approach, base on orientation field, the special masks are proposed, which allow to detect a unique reference point consistently and accurately for all types of prints.

2 Direction image determination

The analyzed $M \times N$ image (fingerprint) is binarized firstly and the binarization threshold has been fixed on the level:

$$T = \frac{\sum_{y=1}^{N} \sum_{x=1}^{M} v(p_{xy})}{M \cdot N} - 30 \qquad (1)$$

where:

$v(p_{xy})$ – the value of a pixel at point p_{xy},

N, M – vertical and horizontal dimension of fingerprint image, respectively.

The constant 30 which occurs in equation (1) was fixed experimentally, and allows us to get the better binarization effect for scanned fingerprint im-

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ages with dark background. In presented implementation, fingerprint images have had dimension 512×512 and with density 500 dpi have been scanned.

To decide the ridge direction of each pixel in the image, the ridge direction of a given raw pixel p_{xy} into directions i $(i = 0, 1, \ldots, 7)$ has been divided in a 9×9 window with the pixel in the center [3] (Fig. 1 b). The values of pixels in eight directions (at positions marked by numbers 0,1,...,7) are added together to obtain sums $s_0, s_1, \ldots, s_7$. The sums s_i are equivalent to convolving the image with 9×9 masks m_i, where each mask has value of 1 at positions where block shown in Fig. 1 b has values i, and 0 elsewhere.

In next stage, for indices i min/max values are computed:

$$i = \begin{cases} s_d = \arg\limits_{i=\{0,1,..,7\}} \{\max(s_i)\} & \text{for } p_{xy}^{bin} = 1 \\ s_l = \arg\limits_{i=\{0,1,..,7\}} \{\min(s_i)\} & \text{for } p_{xy}^{bin} = 0 \end{cases} \tag{2}$$

where: p_{xy}^{bin} – is a pixel value in binarized fingerprint.

The direction at pixel is defined by means of s_d value if the central pixel is located on a ridge (black area), and by the s_l value if the central pixel is located in a valley (white area). From equation (2), indices image can be prepared. Such image can also be called direction image. Unfortunately, obtained values treated as direction for each pixel are usually noisy, therefore they should be smoothed and averaged in a local neighborhood. In our application, as smoothing operation the *mode* function has been applied. The function mode computes the mode of the given data and the mode is defined as observation with the highest frequency. In other words, mode function can be treated as measure of central tendency. For example $d = mode(a, b, c, d, d, d, e, f, g)$. If there is more than one observation with the modal frequency, then choice is arbitrary. Results of mentioned operations are shown on Fig. 1.

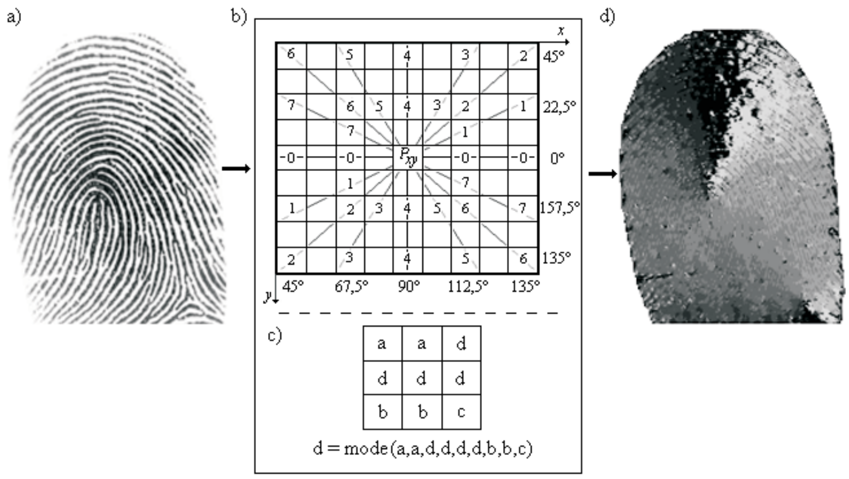

Fig. 1. a) a given fingerprint, b) the 9×9 mask to compute the ridge directions, c) 3×3 mode filter mask, d) directions image.

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For a given fingerprint (Fig. 1 a), directions image has been computed (Fig. 1 d). Such image is additionally filtered by means of 3×3 averaging filter mask, which works like the mode function (Fig. 1 c).

3 A new method of reference point determination

From directions image, the orientation field has been prepared [2, 4]. The orientation represents the local orientation of the ridges contained in the fingerprint. Directions image from Fig. 1 d into 9×9 blocks (windows) has been divided. In each block, dominant direction (the most frequently occurring direction) like previously was calculated. From the gradient information the orientation angle is estimated. The 8 directions (see Fig. 1 b) in each block is stored as table. This table can be presented as image (although it is not necessary), where each direction is performed as appropriate line. For example, for angle 0^0 horizontal line is performed, for angle 90^0- vertical, and so one by step $22,5^0$ for another direction lines. In next stage background is eliminated and only foreground is used. If in a given 9×9 block at least one black pixel can be found, then whole block create part of orientation field, otherwise such block is treated as background and is rejected. The orientation field of fingerprint shown Fig. 2 a.

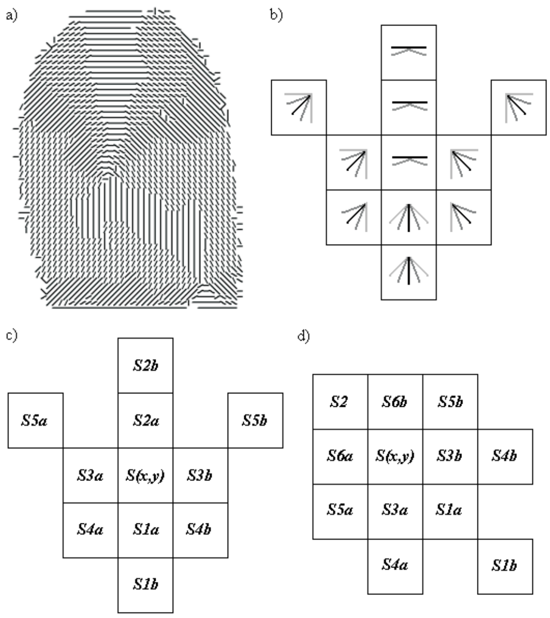

Fig. 2. a) the appropriate orientation fields obtained from directional image (see Fig. 1 d), b) features of identification mask, c,d) the identification masks for 0^0 and $+45^0$, respectively

After background elimination the orientation field is smoothing with the aid of mode mask, similar as previously.

In the last stage the reference point is determined. Because print of finger can be impressed in different manner, influence of rotation should

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be eliminated. In our method orientation field image is filtered by means of appropriates masks. That masks have special construction, what allows to collect fingerprints located in $0^0, \pm 45^0, \pm 90^0$. Proposed masks are called *identification masks*. Fig. 2 a presents identification features of each mask. A special arrangement of short lines in each cell characterizes ridges in a human fingerprint. Such ridges distribution has been established experimentally. Such approach is very efficient and it is equivalent to minutiae detection method [5], but unlike another methods [1, 4, 6] our solution gives faster reference point detection. By means of identification masks, which explore whole orientation field, fingerprint features represent by appropriate mask are sought. The masks for angles 0^0 and $+45^0$ presents Fig. 2 c. Because it is not known, how fingerprint was impressed, orientation field is filtered in turn by all masks. Finally, each identification mask more than one reference point can indicate. All identification masks into cells are split. The cell $S(x, y)$ indicate direction at point x, y in orientation field. The 8 directions in orientation field are represented by means of numbers 0, 22.5, 45, 67.5,...,157.5 (see Fig. 1 b).

From orientation field (Fig. 2 a) the reference point for the angle 0^0 can be determined if the global condition is fulfilled:

$$\begin{aligned}
&\textbf{If } (-22,5^\circ \geq S(x,y) \geq 22,5^\circ) \textbf{ and not } (-22,5^\circ \geq S1a \geq 22,5^\circ)\\
&\quad \textbf{and not } (-22,5^\circ \geq S1b \geq 22,5^\circ) \textbf{ and } (-22,5^\circ \geq S2a \geq 22,5^\circ)\\
&\quad \textbf{and } (-22,5^\circ \geq S2b \geq 22,5^\circ) \textbf{ and } (0^\circ \geq S3a \geq 90^\circ)\\
&\quad \textbf{and } (90^\circ \geq S3b \geq 180^\circ) \textbf{ and } (22,5^\circ \geq S4a \geq 90^\circ)\\
&\quad \textbf{and } (90^\circ \geq S4b \geq 157,5^\circ) \textbf{ and } (0^\circ \geq S5a \geq 90^\circ)\\
&\quad \textbf{and } (90^\circ \geq S5b \geq 180^\circ)\textbf{;}
\end{aligned} \tag{3}$$

Similarly, for angle $+45^0$, the reference point can be determined if the global condition of orientation field can be fulfilled:

$$\begin{aligned}
&\textbf{If } (22,5^\circ \geq S(x,y) \geq 67,5^\circ) \textbf{ and } (90^\circ \geq S1a \geq 180^\circ)\\
&\quad \textbf{and } (90^\circ \geq S1b \geq 180^\circ) \textbf{ and } (0^\circ \geq S2 \geq 90^\circ)\\
&\quad \textbf{and } (45^\circ \geq S3a \geq 157,5^\circ) \textbf{ and } (112,5^\circ \geq S3b \geq 225^\circ)\\
&\quad \textbf{and } (45^\circ \geq S4a \geq 157,5^\circ) \textbf{ and } (112,5^\circ \geq S4b \geq 225^\circ)\\
&\quad \textbf{and } (45^\circ \geq S5a \geq 157,5^\circ) \textbf{ and } (112,5^\circ \geq S5b \geq 225^\circ)\\
&\quad \textbf{and } (0^\circ \geq S6a \geq 90^\circ) \textbf{ and } (0^\circ \geq S6b \geq 90^\circ) \textbf{ ;}
\end{aligned} \tag{4}$$

For remained masks, performed conditions (4) and (5) should be modified by appropriate rotation of the masks. In the worst case, each identification mask can point different reference points, but it is well known that for fingerprint only one reference point can be indicated. From this reason, for all potential reference points, detected by means of identification masks (Fig. 2 c), so-called *influence coefficients* have been estimated. The influence coefficients ($inco$) is calculated as follow:
For angle 0^0:

$$\textbf{If } (S(x,y) = S2a) \textbf{ then } inco := inco + 1;$$

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If $(S5a <> 90^\circ)$ **or** $(S5b <> 90^\circ)$ **then** $inco := inco + 1$;

If $(|S1a - S(x,y)| = 90^\circ)$ **or** $(|S1b - S(x,y)| = 90^\circ)$ **then** $inco := inco + 1$;

For angle $+45^0$:

If $(S(x,y) = S2)$ **then** $inco := inco + 1$;

If $(S5a \leq 22,5^\circ)$ **or** $((S5b \geq 90^\circ)$ **and** $(S5b \leq 135^\circ))$ **then** $inco := inco + 1$;

If $(|S1a - S(x,y)| = 90^\circ)$ **or** $(|S1b - S(x,y)| = 90^\circ)$ **then** $inco := inco + 1$;

Remained the influence coefficients are calculated similarly, and only appropriate values of angles should be changed: for $-45^0, \pm 90^0$, respectively. Additionally, the next principles are considered:

– if two (or more) references points is located in a local neighborhood, then value of the *inco* coefficient is increased of 4,

– for the lowest located reference point, its *inco* value is increase of 5.

– potential reference point which lies at a distance less than 8 pixels from edge background is rejected.

Finally, the point which has the largest *inco* coefficient, will be classified as reference point.

Proposed detection of reference point together with the 2D Gabor filtering method [2] can be used to fingerprint matching.

4 Conclusions

In this paper, a new method to locate a unique reference point has been presented.

Since human experts may not be able to locate the pixel wise accurate reference point, we propose the new method which allow to determine such point. The our method base on so-called *identification masks*, which was designed on the basis of human finger print analysis. For proposed masks, the *influence coefficients* have been stated. Proposed method with complete algorithm described in [2, 7] has been compared. Complete results could not be included as over 100 fingerprints from database were tested. The described method with the aid of the FVC2000 fingerprint database has been tested. Mentioned data collection includes varying quality fingerprint images.

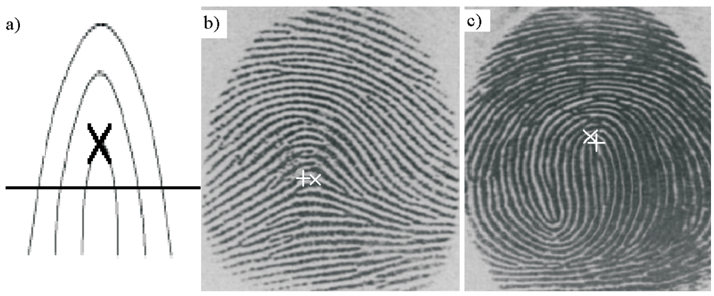

Fig. 3. a) The perfect reference point location, b,c) reference point determination for different fingerprints quality from the FVC2000 database.

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Taking into account paper length restrictions, only main differences between algorithms have been stated. Fig. 3 presents obtained results of reference point location. In experiments the reference points by signs '+' or 'x' have been marked. Our reference point location by means of 'x' sign is indicated.

In any fingerprint can be shown points on the basis of which reference point can be detected. Such objects can be delta points, the Galton line or the set of minutiaes. In our approach, the perfect reference point should be placed at the point with maximum curvature on the convex of fingerprint ridge (Fig. 3 a) [4, 5, 6].

From Fig. 3 follows, that reference points are located very close each other, though clearly at different places. From conducted investigations differences between reference points location are always not greater that 9 pixels, where difference is determined between middles of appropriate markers. From observation follows, that our reference point location in most cases more precisely corresponds to perfect reference point definition.

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