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THE LIP PRINT RECOGNITION USING HOUGH TRANSFORM

This paper presents the new method of lip print recognition. Lip print analysis is based on sulcus-topology features manifested on human lips. The structure of the characteristic lip lines is transformed to a digital image and classified using the Hough transformation. The proposed algorithm gives good level of recognition accuracy and can be used in biometric applications and applied in forensic services.

1. INTRODUCTION

Reliable personal identification is one of the most difficult tasks of modern forensic science and biometrics. Nowadays, there are many biometric techniques, where human body or human behaviour can be measured. Such elements can be treated as special patterns in the processes of person identification or verification. Different techniques of human lips analysis were introduced in many works [2,3,4,9,10].

Lips are formed in the embryonic period of human development together with the form of face shape. During this period also background of lips surface is formed. Surface of human lips is covered by numerous depressions (grooves) which can be reflected as a set of lines arranged in various shapes. The lip image and its structure are unique for each person. This means that there are no two individuals who have identical lip pattern [4]. Personal identification based on lip traces is possible due to the fact that lip grooves, similar as finger imprint ridges, have the following properties: permanence, indestructibility and uniqueness [1,2,3,11].

The study of furrow and groove patterns occurred in human lips is called cheiloscopy [9]. Although, possibilities of this forensic technique are still insufficiently recognized, it is slowly accepted and introduced to practice all over the world. In many countries, including Poland, lip traces are successfully used to identify criminals during investigations [5].

Method of lip print analysis proposed in this paper consists of three stages:

- Pre-processing, where image optimization is carried out.
- Feature extraction, where a unique set of lip features is extracted.
- Recognition, where lip print is compared with patterns stored in a database.

2. PRE-PROCESSING

In the first step, lip print is disclosed on a durable surface using a fingerprint powder (different type of powders can be used depending on a surface type). As a surface special backing tapes or specialized papers (cards) can be used. Such disclosed picture is then changed to a digital image by means of scanner – it allows using these images in computer processing.

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During lip print image (Fig. 1a) pre-processing two binarization methods are applied: one for the image background and the other for the lip print area. Therefore image pre-processing consists of two stages:

- Background detection, where the image is converted to a monochrome scale (greyscale) and lip print area is separated from the background.
- Binarization, where the image is converted to a black-white version. After this process the lip pattern is mapped in the black colour.

In some cases lip print image may be scanned as an RGB image. In such case image I (colour image) is converted to greyscale (Fig. 1a), according to the following formula [8]:

$$I^{new}(x,y) = 0.299 I_R(x,y) + 0.587 I_G(x,y) + 0.114 I_B(x,y) \tag{1}$$

where:

$I_R(x,y)$ – value of the component R at the point (x,y) of the image I

$I_G(x,y)$ – value of the component G at the point (x,y) of the image I

$I_B(x,y)$ – value of the component B at the point (x,y) of the image I

On the basis of average brightness of the image I the global background detection threshold γ has been experimentally established:

$$\gamma = 255 - 0.75\left(255 - \frac{\sum_{y=0}^{h-1}\sum_{x=0}^{w-1} I(x,y)}{wh}\right) \tag{2}$$

where:

w – width in pixels of the image I

h – height in pixels of the image I

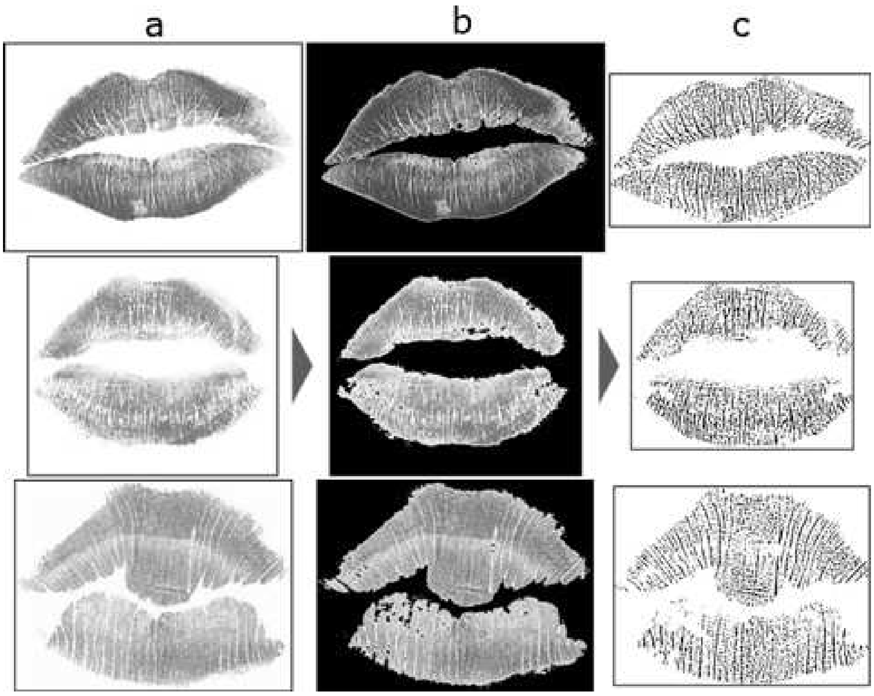

Fig. 1. Pre-processing stages of lip prints: a) lip print image after conversion to greyscale, b) the same images after background detection, c) binarized and cropped image

Inside the area of 7×3 pixels (7 pixels horizontally and 3 pixels vertically), for the each pixel (x, y), its average brightness $d_{x,y}$ is calculated:

$$d_{x,y} = \frac{\sum_{j=y-1}^{y+1}\sum_{i=x-3}^{x+3} I(i, j)}{21} \tag{3}$$

The surrounding area was chosen experimentally.

All $I(x, y)$ pixels for which $d_{x,y} > \gamma$ condition is fulfilled are considered as background pixels. The result of this process shows Fig. 1b where black colour indicates the background areas.

The final stage of the pre-processing is binarization. The main goal of the binarization process is to remove some image artefacts and amplify lip characteristics for further processing.

Binarization is carried out differently in the background and lip print areas. If a pixel belongs to the background it automatically takes the value of 0 (white). Otherwise, if the pixel belongs to the lip print area, reverse automatic threshold $b_{x,y}$ of binarization is applied. Thus the new image $I^{new}(x, y)$ is formed:

$$I^{new}(x, y) = \begin{cases} 1 \text{ for } I(x, y) > b_{x,y} \\ 0 \text{ for } I(x, y) \le b_{x,y} \end{cases} \tag{4}$$

The binarization threshold $b_{x,y}$, similarly as previous, is calculated for each pixel (x, y) inside the area of 9×9 pixels (9 pixels horizontally and 9 pixels vertically). The surrounding area has been also chosen experimentally. The binarization threshold is calculated from the formula:

$$b_{x,y} = 1.1\left(\frac{\sum_{j=y-4}^{y+4}\sum_{i=x-4}^{x+4} I(i, j)}{81}\right) \tag{5}$$

The last step is to remove unnecessary areas around the lip print by cropping the image. This procedure limits the work area. Hence retrieved data are significantly reduced. The final result of binarization and cropping presents Fig. 2c.

3. FEATURE EXTRACTION

After pre-processing stages a unique lip pattern can be then analysed. Manifested on the human lips sulcus-topology features can be easily observed (Fig. 3a) and extracted in the form of a set of segments. Collection of the segments (grooves) can be treated as a lip features vector. Such vectors will be used to determine similarity between lip prints.

The process of feature extraction is composed of the following stages:

– The Hough transform, where straight lines occurring in the lip pattern are detected.
– Detection of segments, which are a substitute of lip grooves.

There are many implementations of Hough transform [6,7]. This method is used to detect geometric objects in raster images (e.g. straight-lines, ellipses or circles). In the presented article so-called standard Hough transform (SHT) is applied to detect straight lines [6]. In proposed approach, additional modification of the SHT has been proposed – it allows removing redundant straight lines, hence SHT is more effective.

In the present implementation the Hough transform consists of the two steps. In the first step pixels belonging to the lip pattern area, described by Cartesian coordinates (x, y), are transferred to space of the polar coordinates (r, θ) in which they form a sinusoidal curves. Polar coordinate space is represented by so-called accumulator array. Analysis is carried out for all pixels (Fig. 1c) belonging to the lip pattern area. On the basis of the $I(x, y)$ coordinates length of the r vector for each value of θ angle is determined, according to the formula:

$$r = x\cos\theta + y\sin\theta \tag{6}$$

where:

$$\theta \in \left\{0, \frac{\pi}{128}, \frac{2\pi}{128}, ..., \pi\right\}$$

Obtained pair of polar coordinates allocates an address of cell in the accumulator array. Allocated in the cell value is then incremented. This way lip print pattern pixels are reproduced in the accumulator array as curves (Fig. 2c).

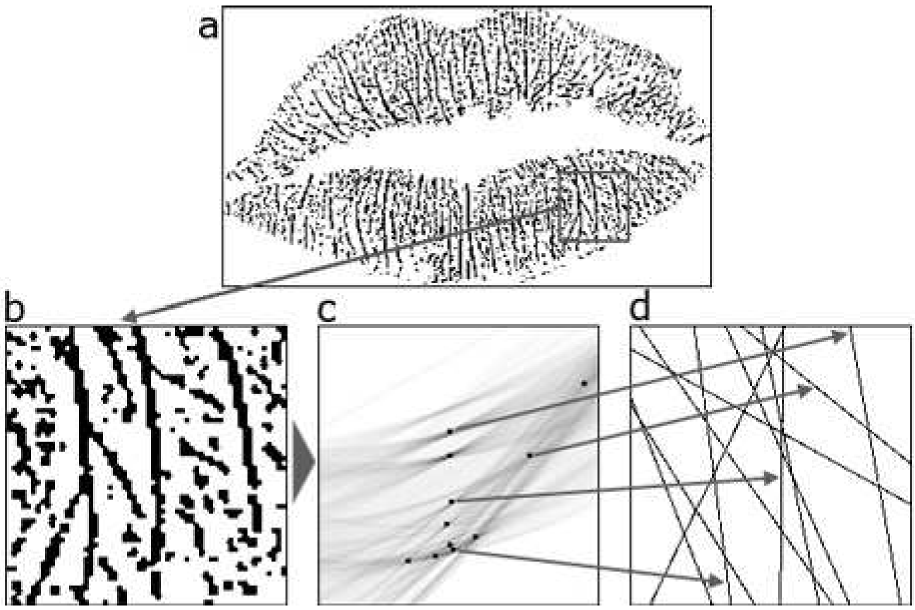

Fig. 2. Hough transformation stages: a) binarized lip print image area, b) magnified lip print grooves sub-area, c) accumulator array of the selected sub-area, d) straight-lines extracted in the sub-area

For every (x, y) pixel equation (6) is solved and accumulator array is appropriately populated. If a set of points forms a straight-line, then the corresponding curves in (r, θ) space intersect at one point (r_0, θ_0). Finally, straight-lines are determined. It can be achieved by analysing the cells of the accumulator array which values are greater than the detection threshold coefficient. The threshold level dtc has been experimentally established ($dtc = 32$).

First, inside of 17×17 area, a cell with a maximum value is localised and registered. Then all cells in the surrounding area are cleared. The coordinates of the registered cell define the parameters (r_0, θ_0) used to designate a straight-line equation:

$$y = \left(-\frac{\cos\theta_0}{\sin\theta_0}\right)x + \left(\frac{r_0}{\sin\theta_0}\right) \tag{7}$$

Fig. 2c presents the straight-lines detected by using Hough transform.

The final stage of feature extraction is detection of segments based on binarized lip print image and a set of straight lines resulted from SHT. Detection of segments consists of the three steps.

In the first step, straight-lines are again transferred to the (x, y) space. The course of the straight-lines is determined in dependence on the range of the θ parameter. If $\theta \in [0^\circ, 45^\circ) \cup (135^\circ, 180^\circ]$ then for each image coordinate x, the corresponding value of the y-coordinate is calculated from the formula:

$$y = round\left(r - xctg\theta\right) \tag{8}$$

If $\theta \in [45^\circ, 135^\circ]$, then for each y-coordinate, corresponding value of the coordinate x is calculated from the simple formula:

$$x = round\left(r - yctg\theta\right) \tag{9}$$

In the next step, points which form the straight-line (Fig. 3c) and overlap the lip pattern (Fig. 3b) are examined. In this implementation so-called segment detection array (Fig. 3d) was used for each straight-line. If the point (x, y) of the straight-line lies in the lip pattern area then value of the corresponding coordinate in the segment detection array is set to 1.

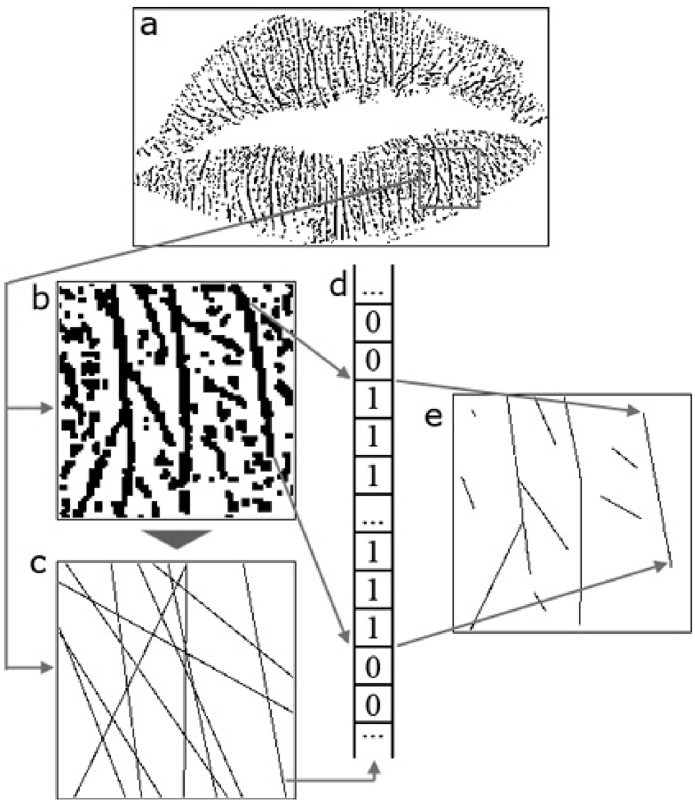

Fig. 3. Stages of the segments detection: a) binarized lip print image area, b) magnified lip print grooves sub-area, c) straight-lines extracted inside the sub-area, d) segment detection array for one of the lines, e) the resultant set of segments

In the last step are determined parameters of the segments corresponding to the grooves in the lips area (Fig. 3e). It was mentioned above, that the segment detection array contains sequences of ones. Geometrical distribution of such values is the same as segments on the Fig. 3e. So, the beginning and the end of each sequence determines the beginning and the end coordinates of the corresponding segment, while number of consecutive ones defines length of segment. Only segments longer than minimum segment length parameter ($msl = 16$) are qualified as substitute of lip grooves (lip sulcus-topology). This parameter was determined experimentally, it increases the efficiency of feature extraction by removing insignificant segments.

4. LIP PATTERN CREATION

Lip pattern corresponds with the groove topology manifested on person's lips. The grooves are characterized by relevant segments, which form the best feature set of the lips.

The procedure, which creates a lip template, is carried out as follows. In the first step, on the basis of different lip prints belonged to one person, a segment set is generated for each lip print. The gathered segment sets of one person are then compared round robin in order to find their similarity coefficient. At each comparison similarity coefficient is in "in-place" incremented. Thus, after all comparisons so-called global similarity factor is determined. During comparison, minimal similarity coefficient is also stored.

In the last step, set of segments with the highest global similarity coefficient is regarded as a lip template. Minimal similarity coefficient is used as a minimum threshold of similarity for this template.

Selected set of segments together with the corresponding the minimum threshold of similarity build a lip pattern (template). Digital lip template is stored in a database and is used in the process of person's identification.

5. LIP RECOGNITION

The procedure for similarity designation of two lip feature vectors is used both in template construction and personal identification/verification. Its task is to define the degree of similarity between two lip prints (while creating a template) or lip print and template (in identification/verification mode). The result of this procedure is so-called global degree of similarity.

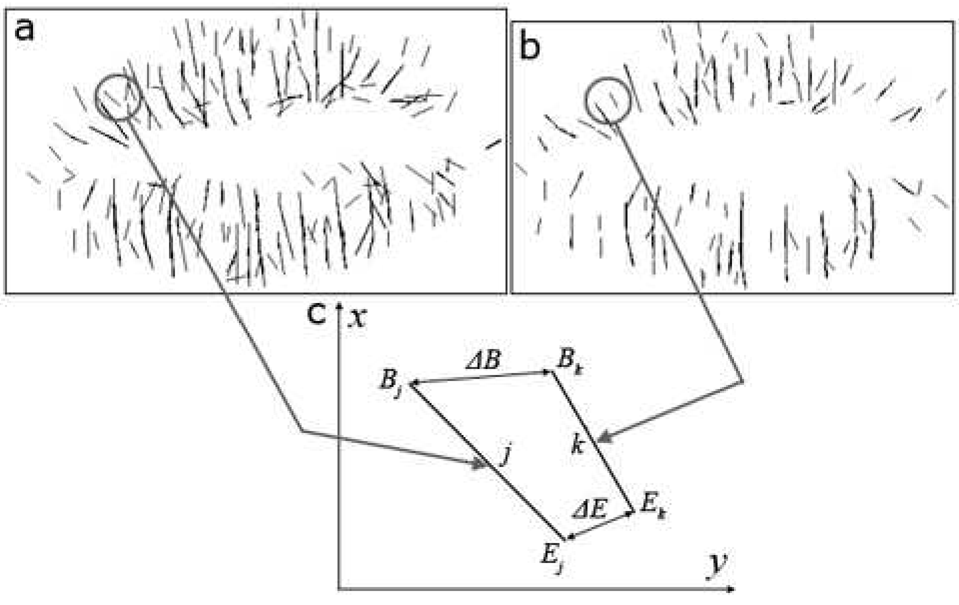

Fig. 4. An exemplary segments comparison process: a) a set of segments in the pattern *J*, b) a set of segments in the pattern *K*, c) designation of the distance between two segments located in the different sets.

Set of segments, obtained during feature extraction process, is represented in the form of list where each element (segment) is defined by the coordinates of its beginning and the end. Then the similarity of two sets of segments is determined. Elements from the set J are compared with the second set K. For each segment $j \in J$ the most similar segment $k \in K$ is searched. The coordinates of beginning and the end of these segments are compared (Fig. 4c) in order to calculate a partial similarity ratio δ_j of the set of segments.

Let $l_J = card(J)$ and $l_K = card(K)$ be a number of elements in sets J and K respectively, then:

$$\delta_j = 1 - \frac{\Delta B + \Delta E}{2\sqrt{256^2 + 256^2}} \tag{10}$$

where:

ΔB – Euclidean distance between beginnings of j and k segments,

ΔE – Euclidean distance between the ends of j and k segments,

$j = 1, ..., l_J$

Due to asymmetry of the segment sets (in the case when $l_J \neq l_K$), the comparison is carried out inversely also – elements of the set K are compared with elements of the set J. In this way, a list of δ_k factors is obtained, similarly as previous and $k = 1, ..., l_K$.

Finally, when comparison process is finished, values δ_j and δ_k are added and their average value is calculated. It is so-called a global similarity coefficient:

$$S = \frac{\sum_j \delta_j + \sum_k \delta_k}{2} \tag{11}$$

The factor S is used to estimate similarity of lip features represented by means of the set of segments.

6. INVESTIGATION RESULTS

The present study point out that proposed identification and verification procedure is usefulness. In the comparative tests FAR and FRR error rates as well as efficiency (percentage of correctly classified lip prints) value were evaluated. During tests the set of 40 lip prints (gathered from 10 individuals) was used. The investigation results are presented in Table 1.

Table 1. Investigation results

	FAR	FRR	Efficiency
Identification	30%	0%	70%
Verification	17%	0%	85%

From carried out investigation follows that the FRR factor is equal 0% in both identification and verification modes. The FAR factors are different and depend on the mode of work of biometric system. System efficiency is higher for the verification mode and is equal to 85%. This is a highly satisfactory outcome, since this allows us to use system as independent lip print recognition classifier.

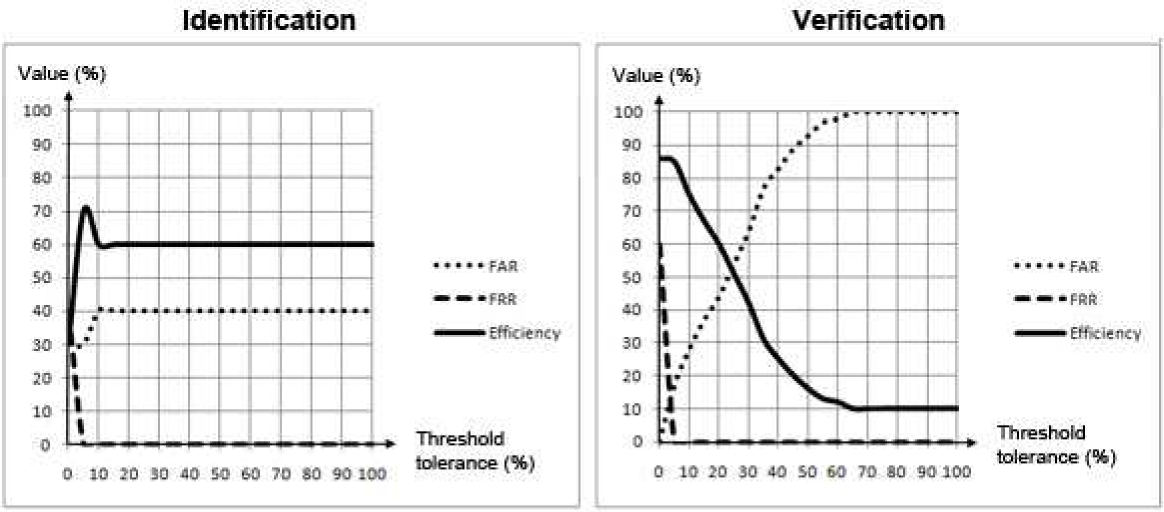

Fig. 5. FAR, FRR and efficiency charts for identification and verification mode of the biometric system

Fig. 5 shows FAR, FRR and efficiency curves for both identification and verification modes. The system works the best and stable for threshold tolerance parameter between 4% and 6%.

7. CONCLUSIONS

Algorithms proposed in the article are not a perfect solution. Applied in this paper Hough transform detects only straight-lines. In fact, lip pattern includes also more complex shapes which should also be examined. However the obtained results are promising and allow to take additional researches in the future. Further works will also take into account the shape, size and geometrical proportions of the lips and its regions.

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