Lip Print Recognition Method Using Bifurcations Analysis

Krzysztof Wrobel(✉), Rafał Doroz, and Malgorzata Palys

Institute of Computer Science, University of Silesia,
ul. Bedzinska 39, 41-200 Sosnowiec, Poland
{krzysztof.wrobel,rafal.doroz,malgorzata.palys}@us.edu.pl
http://zsk.tech.us.edu.pl, http://biometrics.us.edu.pl

Abstract. The paper presents a method of automatic personal identification on the basis of an analysis of lip prints. The method is based on a new approach, in which each lip print is described by bifurcations. In order to extract bifurcations, a method for lip print pre-processing was proposed. The bifurcations obtained were compared with each other using the similarity coefficient developed for the needs of this study. The effectiveness of this coefficient was verified experimentally.

Keywords: Biometrics · Lip print · Image pre-processing · Bifurcations

1 Introduction

Currently, the need for implementing modern systems for personal identification or verification is constantly growing. Such systems are often based on biometric methods. The most popular biometric identification methods include: signature recognition, iris recognition, fingerprint recognition and profiling [1,3,6,7]. There are also other methods, e.g. cheiloscopy, which are becoming more popular.

The term *cheiloscopy* is derived from Greek words: *cheilos* – lips, *skopeo* – to observe. Cheiloscopy is a domain of criminology which deals with the examination of lip prints and the personal identification based on lip prints [10,12]. The vermilion border (Latin: *rubor labiorum*) is a demarcation between the outer layer of a lip and its inner part. In other words, it is an intermediate part of a lip.

In cheiloscopy, the identification of a given person takes place on the basis of an analysis of characteristic features located in the vermilion border. A single lip print contains, on an average, 1145 individual features forming a unique pattern different for each person [8]. This is a very large number as compared with a fingerprint, in which approx. 100 individual features can be identified. There is no doubt that such a huge potential of lip prints can be used for personal identification [15–17]. Thank to this, in recent years, apart from applications of cheiloscopy in criminology, research are conducted on its use for biometric personal identification and verification.

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So far, there are a few methods for lip print examinations. These methods use, inter alia, statistical analyses [8], similarity coefficients [4], lip shape analyses [5], Dynamic Time Warping [13], segmentation [9], Hough Transform [17]. In these methods, only single features, such as lines forming the lip print pattern, are analysed and compared with each other. A new approach was proposed in this study. It involves not only analyses of single features, but also the determination and investigation of the relationships between them.

2 Proposed Method

The method proposed in this study is used to determine the similarity between two lip prints compared with each other. The comparison takes place by designating a set of features in every image and then comparing them with each other. As the result of such a comparison, a set of the most similar features in both images is obtained. On the basis of the set obtained in this way, the coefficient of similarity between images is determined. The similarity coefficient allows deciding whether the lip prints compared belong to the same person. Steps of this method are shown in the block diagram (Fig. 1).

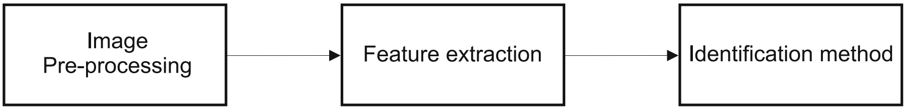

Fig. 1. Block diagram of the proposed method

2.1 Image Pre-processing

Accurate and correct acquisition of the feature set is one of the factors determining the effectiveness of the method presented. Similarly to fingerprints, lip prints may have a poor quality or have a low contrast and be noised. This causes that the extraction of features from such a print is not an easy task. An example of a poor quality print is shown in Figure 2.

In order to expose the characteristic features better, the image is pre-processed. In the first stage of pre-processing, each print from the test database was subjected

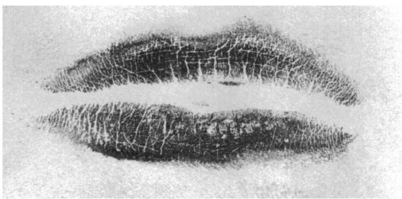

Fig. 2. An example of a poor quality lip print

to the process of linear contrast stretching [2]. This process consists in increasing the differences in the brightness level between pixels of the image. If the lip print is characterized by a low contrast, it becomes clearer and therefore easier for analysing. The effect of linear contrast stretching is shown in Figure 3a.

Unfortunately, during the acquisition of the mouth image, the areas around the mouth, such as the cheeks or chin, may also be registered. In further steps of the method, they are interpreted as elements of the lip print, which may cause errors in recognition. Therefore, the next step is to locate the area of the mouth (upper and lower lips), and then to assign the black colour to all the pixels that do not belong to this area.

The mouth area is located by analysing the brightness of pixels in the image. As shown in Figure 3a, the lip print area is darker. The colour of the pixels with brightness lower than a certain threshold is set to black. In this study, the threshold value was determined using the method proposed by Ridler-Calvard [14]. The Ridler's-Calvard's algorithm chooses an initial threshold and then iteratively calculates the next one by taking the mean of the average intensities of the background and foreground pixels determined by the first threshold, repeating this until the threshold converges. Figure 3b shows the effect of the described operations.

The image prepared in this way is subjected to the binarization process. The pixel examined in the image will become white, if the level of its brightness is higher than the average brightness level in the area around it. It was assumed that the size of the analysed area is 7x7 pixels. Otherwise, the pixel will become black. Then, the image is subjected to the operation of negation. As a result, an image is obtained, in which black pixels form the lip print pattern. Such an image is shown in Figure 3c.

As a result of the use of the methods described so far, the lines in the image that form the lip print pattern have a different thickness. This hinders the extraction of bifurcations occurring in the image, which are used in a further part of the study for determining the similarity between lip prints. In order to eliminate this inconvenience, the image is subjected to the process of skeletonization. As a result, an image is obtained, in which all lines have a thickness of one pixel. The Pavlidis method [11] was used in the studies. The result of using this method is shown in Figure 3d. The features to be compared are extracted from the image prepared in this way.

2.2 Feature Extraction

Under the method presented, lower and upper bifurcations were compared in order to determine the similarity of lip prints. Such bifurcations belong to the most frequently occurring features that can be extracted in the easiest way. The set of bifurcations forms a unique pattern for each person, on the basis of which it is possible to identify a given person. For this reason, in relation to a single bifurcation, the features describing relationships between a given bifurcation and the remaining bifurcations were analysed in addition to the determination of its coordinates and the orientation angle.

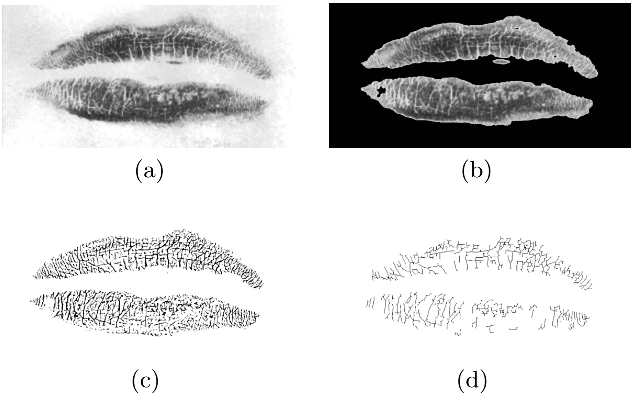

Fig. 3. (a) Image after the linear contrast stretching, (b) image after assign the black colour to all the pixels that do not belong to this mouth area, (c) image after the binarization process, (d) image after the process of skeletonization

In order to find bifurcations, all black pixels in the lip print are analysed. If an analysed pixel is to be considered as the centre of a bifurcation, two conditions must be fulfilled. Firstly, bifurcations are characterized by the presence of three black pixels around the pixel being analysed. This condition is checked by placing a 3x3 mask on the analysed pixel. The sum of black pixels in the mask must equal four. An example of an identified bifurcation is shown in Figure 4.

The second condition is that the minimum length of components of a bifurcation is equal to four pixels, including the pixel being analysed. A lack of the above condition resulted in the detection of pixel clusters that were not bifurcations. An example of such clusters is presented in Figure 4a. The analysis of the length of components of the bifurcation was carried out by placing a mask (with the size of 7x7 pixels) on the pixel being analysed. Then, the black pixels located only on the edges of the mask (Fig. 4b) are summed up. If the sum equals three, the coordinates of the pixel being analysed will be regarded as the coordinates of the bifurcation. A pixel with the coordinates (x, y) which satisfies the above two conditions is treated as the centre of the bifurcation.

The orientation angle is determined for the bifurcation in accordance with the assumptions of the method. In order to determine this angle, values of three angles (Ω, β, α) between the arms of the bifurcation need to be found. Examples of such angles are shown in Figure 5a. The arm, which together with the remaining arms forms two largest angles, determines the direction of the bifurcation. The θ angle between this direction and the X axis is called the bifurcation orientation angle (Fig. 5b). The arrangement of bifurcations in a lip print in relation to each other is unique to each person. The coordinates and orientation angles of each bifurcation in relation to adjacent bifurcations form systems of bifurcations. It was assumed that the two bifurcations described by the coordinates

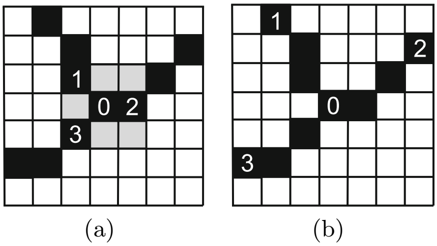

Fig. 4. An example of a bifurcation. The analysed pixel is designated with the number 0.

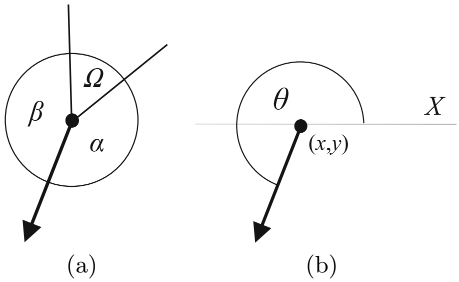

Fig. 5. (a) The Ω, β and α angles between arms of the bifurcation. The direction of the bifurcation is marked with a bold line, (b) the bifurcation orientation angle determined.

$(x_i, y_i), (x_j, y_j)$ and the θ_i and θ_j angles are adjacent, if the following conditions are fulfilled:

$$(x_i - dist < x_j < x_i + dist) \text{ and } (y_i - dist < y_j < y_i + dist), \tag{1}$$

$$|\theta_i - \theta_j| < ang, \tag{2}$$

where:
dist – the maximum accepted distance between centres of bifurcations,
ang – the admissible difference between the bifurcation orientation angles.

Therefore, the lip print *Lip* can be described with the use of a set containing p bifurcation systems:

$$Lip = \{s_1, s_2, ..., s_p\}. \tag{3}$$

Bifurcation systems consist of a set containing three features (d, α, β) that describe the relationships between the bifurcations. A single relationship is described by the following features:
d – the Euclidean distance between the centre of the analysed bifurcation and the centre of an adjacent bifurcation,
α – the angle between the direction of the analysed bifurcation and the section connecting the centre of the bifurcation with the centre of an adjacent bifurcation,

β – the angle between the orientation angle of the analysed bifurcation and the orientation angle of an adjacent bifurcation.

An example of a bifurcation system with features marked on it is shown in Figure 6.

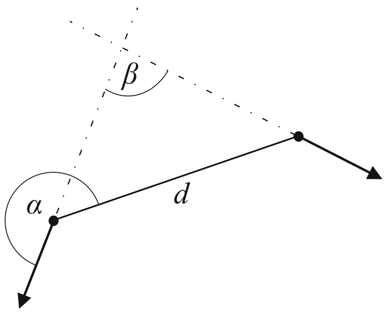

Fig. 6. A bifurcation system with features marked on it

The relationships determined for each bifurcation can be presented in a tabular form. Examples for the three bifurcations are shown in Table 1.

Table 1. Examples of relationships between the three bifurcationsand adjacent bifurcations

Analysed bifurcation			**Adjacent bifurcation**			
no.	**coordinates** (x, y)	θ	**no.**	d	α	β
1	(127, 210)	51	2	68	178	103
			3	47	77	87
			4	51	114	129
			11	39	270	38
			14	71	15	137
2	(86, 148)	163	1	68	116	103
			4	59	135	124
			5	57	192	141
			8	57	276	17
			9	70	47	8
3	(102, 198)	347	1	47	177	87
			4	39	118	83
			5	71	106	39
			6	67	34	82
			14	73	265	169

A single bifurcation system can also be presented in the form of a bifurcation matrix:

$$s_i = \begin{bmatrix} d_1^i & \alpha_1^i & \beta_1^i \\ d_2^i & \alpha_2^i & \beta_2^i \\ \vdots & \vdots & \vdots \\ d_n^i & \alpha_n^i & \beta_n^i \end{bmatrix}, \tag{4}$$

where:
s_i – the matrix determined for the i-th system of bifurcations,
n – the number of triple features describing the system.

2.3 Lip Prints Identification Method

In practice, many characteristic features can be found on lip prints. It often happens that similar characteristic features are present in the same places of lip prints obtained from different people, which makes the identification more difficult. This fact was used for developing a new coefficient of similarity between lip prints. This coefficient is based on the observation that the probability of occurrence of two identical bifurcation systems in different individuals is smaller than the probability of occurrence of two identical bifurcations. Therefore, the method presented here analyses not only single bifurcations, but also bifurcation systems.

The lip print identification method consists in comparing a given lip print with lip prints of other people contained in the database. In the first step of this method, the similarity between bifurcation matrices is determined for two lip prints being compared. Each row of the matrix includes three features (d, α, β). In order to compare two bifurcation matrices s_k and s_l derived from two lip prints being compared (Lip_1 and Lip_2), the following similarity coefficient was developed:

$$sim(s_k, s_l) = \frac{1}{n}\sum_{i=1}^{n} \min_{j=1,...,m} \{|d_i^k - d_j^l| + |\alpha_i^k - \alpha_j^l| + |\beta_i^k - \beta_j^l|\}, \tag{5}$$

where:
$s_k = (d_i^k, \alpha_i^k, \beta_i^k) \in Lip_1$ – i-th row of the bifurcation matrix s_k,
$s_l = (d_j^l, \alpha_j^l, \beta_j^l) \in Lip_2$ – j-th row of the bifurcation matrix s_j,
n – number of rows in the bifurcation matrix s_k,
m – number of rows in the bifurcation matrix s_l.

The advantage of the coefficient given by the formula (5) is that it can compare the bifurcation systems described by a matrix with different numbers of rows.

The similarity between the compared lip prints is determined on the basis of the values of the similarity between individual bifurcation systems. Let the first lip print be represented by the set of bifurcation systems $Lip_1 = \{s_1^1, s_2^1, ..., s_p^1\}$, while the second image by the set $Lip_2 = \{s_1^2, s_2^2, ..., s_q^2\}$. The similarity between the lip prints is determined using the following formula:

$$SIM(Lip_1, Lip_2) = \frac{1}{p} \sum_{i=1}^{p} \min_{j=1,\ldots,q} \{sim(s_i^1, s_j^2)\}, \tag{6}$$

where:
p – number of bifurcation systems in the lip print Lip_1,
q – number of bifurcation systems in the lip print Lip_2.

The lower the value of the similarity coefficient SIM, the more similar the lip prints. After a comparison of the lip print analysed with all the lip prints in the database, the lip print for which the lowest value of the similarity coefficient SIM was obtained indicates the person who provided the lip print.

3 Experiments and Results

The effectiveness of the method was verified experimentally. The database used for the studies consisted of 120 lip prints obtained from 30 people (4 prints per person). Each lip print was adequately prepared using the methods described in previous sections. The prints were compared with each other using the round-robin method. As a result of the comparison of two prints, the value of the similarity between them was obtained. During the studies, various values of the *dist* and *ang* parameters used at the stage of feature extraction were analysed. These parameters were changed in the following ranges:

– *dist* parameter from 10 to 45, with the step 5,
– *ang* parameter from 5 to 25, with the step 5.

The total number of the parameter sets created was 40. Value of EER was determined for each set of parameters. The parameter sets, for which 10 lowest values of EER were obtained, are shown in Table 2.

Table 2. The EER values obtained for different combinations of values of the parameters used in the identification method

Parameter		**EER [%]**
dist	***ang***	
20	5	23.04
15	5	23.88
15	10	24.05
20	10	24.40
10	15	24.74
15	15	25.39
25	15	25.48
20	20	25.56
10	25	25.63
10	20	25.66

When analysing the results presented in Table 2, it can be seen that the best value of EER 23% was obtained for the values $dist = 20$, $ang = 5$. Then the impact of the *ang* parameter on the results obtained was analysed. The analyses were performed for the following values of the *dist* parameter: 10, 15, 20, 25. The results are presented in the Figure 7.

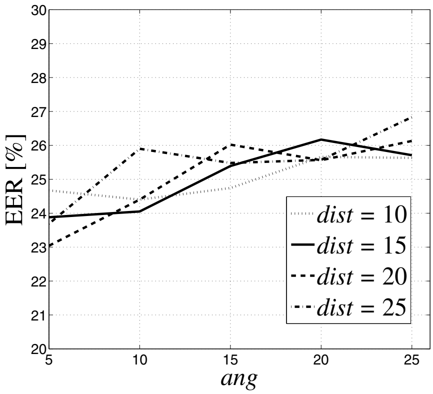

Fig. 7. The impact of the *ang* parameter on the results obtained

As it appears from the diagram, an increase in the value of the *ang* parameter results in an increase in the value of EER, regardless of the *dist* value. The analysis indicates that in order to achieve the best possible results, only the bifurcations with similar orientation angles should be compared. This is consistent with intuition.

4 Conclusions

The paper presents a new method of personal identification based on lip prints. The solution presented here can be easily implemented, while the modular design facilitates future modifications. During the studies, the values of the parameters used in this method were analysed. The best result of EER was at a level of approx. 23%. Considering the fact that there is a small number of solutions for automatic lip print identification, the result obtained can be considered as satisfactory.

During the studies, there were observed situations where some pixels imitated bifurcations that in reality did not exist in the lip print pattern. Such bifurcations may have a negative impact on the identification results. In connection with this fact, further work will focus on developing other methods for pre-processing and extraction of bifurcations, which will eliminate the problem in question. Weights of individual features will be introduced, which will allow determining their impact on the research results.

References

1. Agarwal, G., Ratha, N., Bolle, R.M.: Biometric verification: looking beyond raw similarity scores. In: Workshop on Multibiometrics (CVPR), New York, pp. 31–36 (2006)
2. Al-amri, S.S., Kalyankar, N.V., Khamitkar, S.D.: Linear and Non-linear Contrast Enhancement Image. International Journal of Computer Science and Network Security (IJCSNS) **10**(2), 139–143 (2010)
3. Bhatnagar, J., Kumar, A.: On some performance indices for biometric identification system. In: Lee, S.-W., Li, S.Z. (eds.) ICB 2007. LNCS, vol. 4642, pp. 1043–1056. Springer, Heidelberg (2007)
4. Cha, S.: Comprehensive Survey on Distance/Similarity Measures between Probability Density Functions. International Journal of Mathematical Models and Methods in Applied Sciences **1**(4), 300–307 (2007)
5. Choras, M.: The lip as a biometric. Pattern Analysis And Applications (Springer) **13**, 105–112 (2010)
6. Doroz, R., Wrobel, K.: Method of signature recognition with the use of the mean differences. In: Proceedings of the 31st International IEEE Conference on Information Technology Interfaces (ITI 2009), Croatia, pp. 231–235 (2009)
7. Kasprowski, P.: The impact of temporal proximity between samples on eye movement biometric identification. In: Saeed, K., Chaki, R., Cortesi, A., Wierzchoń, S. (eds.) CISIM 2013. LNCS, vol. 8104, pp. 77–87. Springer, Heidelberg (2013)
8. Kasprzak, J., Leczynska, B.: Cheiloscopy. Human identification on the basis of lip trace (in Polish). KGP, Warsaw, Poland (2001)
9. Koprowski, R., Wrobel, Z.: The cell structures segmentation. In: 4th International Conference on Computer Recognition Systems (CORES 05), pp. 569–576 (2005)
10. Newton, M.: The Encyclopedia of Crime Scene Investigation. Facts on File, New York (2008)
11. Pavlidis, T.: A Thinning Algorithm For Discrete Binary Images. Computer Graphics And Image Processing **13**, 142–157 (1980)
12. Petherick, W.A., Turvey, B.E., Ferguson, C.E.: Forensic Criminology. Elsevier Academic Press, London (2010)
13. Porwik, P., Orczyk, T.: DTW and voting-based lip print recognition system. In: Cortesi, A., Chaki, N., Saeed, K., Wierzchoń, S. (eds.) CISIM 2012. LNCS, vol. 7564, pp. 191–202. Springer, Heidelberg (2012)
14. Ridler, T.W., Calvard, S.: Picture Thresholding Using An Iterative Selection Method. IEEE Transactions On Systems, Man, And Cybernetics **8**(8), 630–632 (1978)
15. Suzuki, K., Tsuchihashi, Y.: Personal identification by means of lip prints. Journal of Forensic Medicine **17**, 52–57 (1970)
16. Tsuchihashi, Y.: Studies on personal identification by means of lip prints. Forensic Science, pp. 127–231 (1974)
17. Wrobel, K., Doroz, R., Palys, M.: A method of lip print recognition based on sections comparison. In: IEEE Int. Conference on Biometrics and Kansei Engineering (ICBAKE 2013), Akihabara, Tokyo, Japan, pp. 47–52 (2013)