lip print recognition,
Generalized Hough Transform,
similarity measure

Krzysztof WROBEL[1], Rafal DOROZ[1]

METHOD FOR IDENTIFICATION OF FRAGMENTS OF LIP PRINTS IMAGES ON THE BASIS OF THE GENERALIZED HOUGH TRANSFORM

The paper presents a new method for identification of fragments of lip print images on the basis of the Generalized Hough Transform (GHT). The effectiveness of this method was verified in practice. The maximum value obtained from the accumulator array after the Hough transform has been assumed as the measure of similarity between a lip print image and a reference object. The advantage of this method is the possibility of use in forensic science to identify persons who left lip prints at crime scenes.

1. INTRODUCTION

Cheiloscopy is a domain of criminology which deals with the examination and identification of lip prints. Edmond Locard, a French criminologist, proposed in 1932, as the first, to use images of human lips for forensic identification. In 1970, Yasuo Tsachihasi and Kazao Suzuki, Japanese scientists, carried out studies on the use of lip images for identification of persons [20], [21].

Up to 1145 individual features can be found on a single lip print [9], [11], [13]. They form a unique pattern, which is different for each person. For comparison, only up to 100 individual features can be observed on a fingerprint. From the studies published in [9] it appears that the pattern of lip grooves is invariable and stable in people aged 21-50. In people over 50, changes in the pattern of *rubor labiorum* are observed, even in 5-year periods. This is caused by ageing and flabbiness of facial muscles. Nevertheless, from the viewpoint of the forensic procedure, the time interval from the moment of securing a lip print at a crime scene to the moment of arresting a suspect on this basis generally does not exceed 6 months. This guarantees the invariability of *rubor labiorum* and allows using cheiloscopy for personal identification.

A practical classification of lip print images was presented by Jerzy Kasprzak, a Polish criminologist [9]. On the basis of the studies carried out on a sample of 1500 lip prints, he distinguished 23 types of individual features that occur in a lip print pattern. He also proposed a division of lip print patterns into four groups: forked pattern - consisting of forks, linear pattern - consisting of straight lines, reticular pattern - consisting of intersections of lines forming a reticulum, and indefinite pattern that occurs when other patterns cannot be distinguished.

[1]University of Silesia, Institute of Computer Science, Będzińska 39, 41-200 Sosnowiec, Poland
e-mail:{krzysztof.wrobel, rafal.doroz}@us.edu.pl.

2. OVERWIEW OF PREVIOUS WORK

The current state of research in the scope of analysis and recognition of lip print images is not as advanced as in the scope of fingerprint identification. This results from the fact that the number of cheiloscopic studies is much lower. The presented methods of lip print identification described in scientific publications can be an example of the current state of research. Table 1 presents a comparison of results obtained with the use of different personal identification methods based on lip print images.

Table 1. Comparison of lip print recognition methods.

Authors and works	**Results**	**Database**
Smacki L., Wrobel K. [18]	EER = 21,3%	120 lip prints (30 persons, 4 lip prints from each person)
Choras M. [4]	EER = 14%	114 lip prints (38 persons, 3 lip prints from each person)
Porwik P., Orczyk T. [14]	EER = 11,5%	120 lip prints (30 persons, 4 lip prints from each person)
Smacki L., Wrobel K., Porwik P. [19]	EER = 21,2%	120 lip prints (30 persons, 4 lip prints from each person)
Wrobel K., Doroz R., Palys M. [22]	EER = 14,90%	45 lip prints (15 persons, 3 lip prints from each person)
Sambit Bakshi, Rahul Raman, Pankaj K Sa [1]	Accuracy = 93% (SIFT) Accuracy = 94% (SURF)	23 lip prints from 10 person
Saptarshi Bhattacharjee, S Arunkumar, Samir Kumar Bandyopadhyay [17]	Efficiency = 91-96%	20 lip prints from 4 persons

Currently, there are no electronic devices designed for acquisition of lip print images. The acquisition takes place by a traditional method with the use of a specialist fingerprinting roller and magnetic powder. For this reason, lip prints image analysis is a very complex task and obtaining good quality images lip print is very difficult. So, most of the error rates are close to between 10% and 20%.

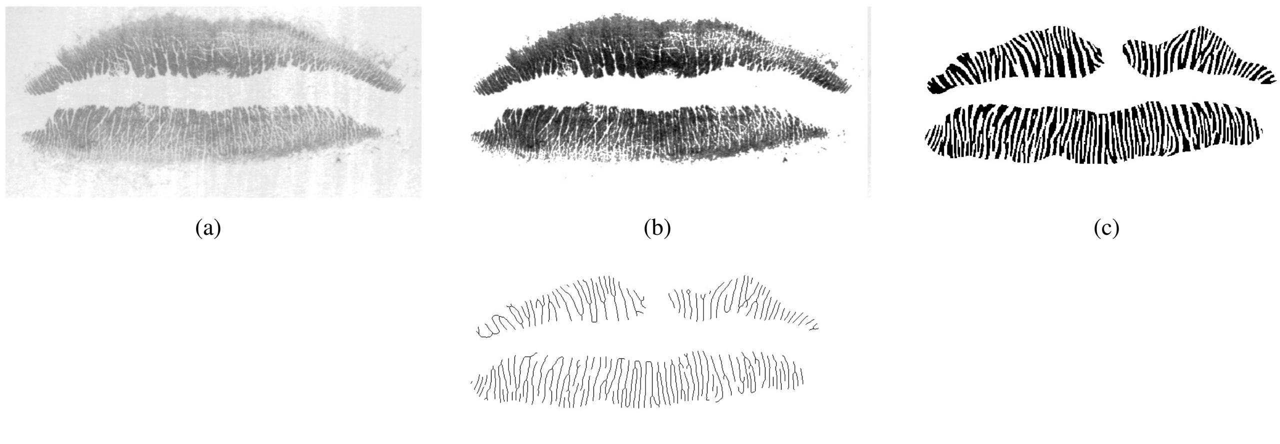
It is worth noting that certain methods compared in Table 1 are based on images obtained from a video camera or photos, for example the method described in this study [4]. Therefore, their use in forensic science is very difficult and sometimes even impossible. In addition, these methods involved analyses of entire lips, which is not effective in forensic applications where only certain fragments of lip prints left at a crime scene are analysed.

3. IMAGE PRE-PROCESSING

The presented method for identification of fragments of lip print images is based on Generalized Hough Transform. In order to transform the input image (Fig. 1a), it has to be properly prepared. In the first stage of processing, the lip print image was separated from the background (Fig. 1b). For this purpose, the image histogram was equalized [3] and then thresholding was performed using the Ridler and Calvard method [16]. The next stage was to improve the quality of the lip print image with the use of the method described in the study [15], which is used also in dactyloscopy (Fig. 1c). As a result of applying this method, a denoised binary image with emphasized lip lines was obtained. The prepared image was additionally submitted to a skeletonization process (Fig. 1d). The Pavildis method described in the study [12] was used. The purpose of the skeletonization was to reduce the number of pixels in the image, which were analysed in the GHT, and thus to speed up the method.

4. GENERALIZED HOUGH TRANSFORM

The Hough transform is a well known and documented method used in image processing. It was introduced by Paul Hough in 1959 as a method for detecting patterns in binary images [6], [7]. Initially, the main purpose of the Hough transform was detection of straight lines in digital images. Later, it was



(a) (b) (c)

(d)

Fig. 1. a) Input image, b) background separation, c) quality improvement, d) skeletonization.

used also for detecting other geometric objects that can be described by parametric equations, such as circles, ellipses or parabolas [5]. In 1981, a modification of the Hough transform was introduced by Dan H. Ballard [2]. This modification is called the Hough transform for irregular objects or Generalized Hough Transform (GHT). In the Generalized Hough Transform, reference objects are not defined by an analytical description. An object searched for in an image is given as a set of pixels [2]. Each point of the object is described by the following parameters:

- distance r of a given pixel from the reference point of the object (x_c, y_c),
- angle α of inclination of the section connecting the reference point of the object with a given pixel in relation to the X-axis.

In our work we assumed that the reference point for the object is this object's center of gravity. These parameters are marked in Fig. 2.

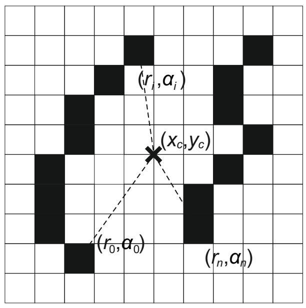


Fig. 2. A fragment of an object with marked values of parameters r and α for three selected points.

The GHT algorithm can be divided into three main parts. In the first part, an R-table array is created for each object. It stores parameters (r, α) for each point of the object. In the second part, an accumulator array (AA) is created and populated. As a result of the back projection process [8], each point of the input image generates a hyper-surface in the accumulator array, which depends on the type of the reference object looked for. The number of hyper-surfaces intersecting at a given point corresponds to the number of common points in the image and in the analysed reference object. In the third part of the algorithm, the maximum value or the values greater than the adopted thresholds are searched for. Coordinates of the AA cells, in which the maximum values were found, indicate the location of the reference object in the analysed image. A detailed description of the Hough Transform and the Generalized Hough Transform is given in [2], [5], [8].

5. THE COURSE AND RESULTS OF THE STUDIES

The study involved 30 lip print images from 10 persons. Three lip prints were taken from each person. In the next stage, one image was selected at random for each person, and then an area with the size of 64∗64 pixels was cut from it. The adopted size is the minimum size that allows representing the shape of adjacent lines and interdependencies between them. The cut image is then treated as forensic trace evidence. As a result, 10 forensic traces were obtained, one from each person. The obtained traces were compared with all lip print images, except for the images from which traces had been cut. Thus, 29 comparisons were made for each single trace, while the total number of comparisons for all 10 traces was 290. The result of each comparison was the value of similarity sim, which had been adopted as the maximum value from the accumulator array after GHT:

$$sim(I, P) = max(AA) \tag{1}$$

where:
I – lip print image,
P – forensic trace.

Results of the comparison of the trace to be identified with the lip prints were recorded in an array, which was then sorted in descending order depending on the similarity coefficient obtained. In Tables 2 and 3 results of the comparison for trace from person no. 02 were presented (before and after sorting).

Table 2. Results of the comparison for trace from person no. 02 (before sorting).

Person	**Lip print**	**Trace from person**	**Similarity value**
01	01	02	54
01	02	02	58
01	03	02	51
02	02	02	81
02	03	02	76
03	01	02	63
⋮	⋮	⋮	⋮
10	03	02	59

In this way, the lip prints with the largest similarity to the trace being identified were placed in the array as the first ones. If a print obtained from the same person was most similar to the trace, the classification was considered to be correct. Otherwise, the trace was considered as incorrectly recognized. The correct recognition rate (CRR) [10] of the method was calculated using the following formula:

$$CRR = \frac{C_n}{T_n} \times 100\% \tag{2}$$

where:
C_n – the number of correct recognitions,
T_n – the total number of all recognitions.

As a result, the CRR of classification at the level of 80% was obtained.

6. CONCLUSIONS

A digital analysis of lip print images is relatively difficult due to low quality of such images. However, as it can be concluded from the presented results of the experiments, the presented method should be suitable for the process of identifying fragments of lip print images. Results of the experiments also encourage for further studies on the proposed method.

Table 3. Results of the comparison for trace from person no. 02 (after sorting).

Person	Lip print	Trace from person	Similarity value
02	02	02	81
02	03	02	76
03	01	02	63
10	03	02	59
01	02	02	58
01	01	02	54
⋮	⋮	⋮	⋮
01	03	02	51

Further studies are planned, which will aim to increase the number of the lip print images being analysed. These studies will also involve determination of the influence of additional parameters, such as resolution of images, rotation of images by a given angle, and the size of the traces cut, on the effectiveness of the classification.

BIBLIOGRAPHY

[1] BAKSHI S., RAMAN R., SA PK., Lip Pattern Recognition based on Local Feature Extraction. Proceedings of 2011 Annual IEEE India Conference (INDICON), India, 2011.

[2] BALLARD D. H., Generalizing the Hough Transform to Detect Arbitrary Shapes, Pattern Recognition, 1981, Vol. 13, No. 2, pp. 111-122.

[3] CASTLEMAN K. R., Digital Image Processing. Printice-Hall, New Jersey, 1996.

[4] CHORAS M., The lip as a biometric, Pattern Analysis and Applications, 2010, Vol. 13, No. 1, pp. 105-112.

[5] DUDA R. O., HART P. E., Use of Hough transformation to detect lines and curve in pictures. Comm. ACM, 1972, Vol. 15, pp. 11-15.

[6] HOUGH P. V. C., Method and Means for recognizing complex pattern. U.S. Patent No. 3069654, 1962.

[7] HOUGH P. V. C., Machine analysis of bubble chamber pictures, Proc. Int. Conf. on High Energy Accelerators and Instrumentation, 1959.

[8] ILLINGWORTH J., KITTLER J., A Survey of the Hough Transform. Computer Vision, Graphic and Image Processing, 1988, No. 44, pp. 87-116.

[9] KASPRZAK J., LECZYNSKA B., CHEILOSCOPY. Human identification on the basis of lip trace (in Polish), 2001.

[10] MANSFIELD A., WAYMAN J., Best practice standards for testing and reporting on biometric device performance. National Physical Laboratory of UK, 2002.

[11] NEWTON M., The Encyclopedia of Crime Scene Investigation, 2008.

[12] PAVLIDIS T., A thinning algorithm for discrete binary images. Computer Graphics and Image Processing, 1980, Vol. 13, pp. 142-157.

[13] PETHERICK W. A., TURVEY B. E., FERGUSON C. E., Forensic Criminology. London: Elsevier Academic Press, 2010.

[14] PORWIK P., ORCZYK T., DTW and Voting-Based Lip Print Recognition System. LNCS, 2012, Vol. 7564, pp. 191-202.

[15] PORWIK P., WIECLAW L., The New Efficient Method of Fingerprint Image Enhancement. International Journal of Biometrics, Inderscience Publisher 2008, Vol. 1, No. 1, pp. 36-46.

[16] RIDLER T. W., CALVARD S., Picture thresholding using an iterative selection method. IEEE Transactions on Systems, Man, and Cybernetics, 1978, Vol. 8, No.8, pp. 630-632.

[17] SAPTARSHI BHATTACHARJEE, S ARUNKUMAR, SAMIR KUMAR BANDYOPADHYAY, Personal Identification from Lip-Print Features using a Statistical Model. International Journal of Computer Applications, 2012, Vol. 55, No. 13, pp. 30-34.

[18] SMACKI L., WROBEL K., Lip Print Recognition Based on Mean Differences Similarity Measure, Advences in Intelligent and Soft Computing (AISC), 2011, Vol. 95, pp. 41-50.

[19] SMACKI L., WROBEL K., PORWIK P., Lip Print Recognition Based on DTW Algorithm. Proceedings of Nature and Biologically Inspired Computing (NaBIC'11), Spain, Salamanca, pp. 601-606.

[20] SUZUKI K., TSUCHIHASHI Y., Personal identification by means of lip prints, Journal of Forensic Medicine, 1970, Vol. 17, pp. 52-57.

[21] TSUCHIHASHI Y., Studies on personal identification by means of lip prints, Forensic Science, 1974, pp. 127-231.

[22] WROBEL K., DOROZ R., PALYS M., A method of lip print recognition based on sections comparison, IEEE Int. Conference on Biometrics and Kansei Engineering (ICBAKE 2013), Tokyo Metropolitan University Akihabara, Tokyo, Japan, 2013, pp. 47-52.