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THEORETICAL ADVANCES

The lip as a biometric

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Abstract In many cases human identification biometric systems are motivated by real-life criminal and forensic applications. One of the most interesting emerging method of human identification, which originates from the criminal and forensic practice, is human lips recognition. In this paper we consider lips shape and color features in order to determine human identity. We present standard and original geometrical parameters used in lips biometric system. Moreover Zernike and Hu moments as well as color features have been used. The presented results are yet not as good as these achieved in other known biometric systems. However, we believe that both lips biometrics as well as our approach and results, are worth to be presented to a wide research community.

Keywords Biometrics · Human identification · Lips recognition · Image analysis · Pattern recognition

1 Introduction

Biometric methods of human identification have gained much attention recently, mainly because they easily deal with most problems of traditional identification. In biometric human identification systems users are identified by who they are, not by something they have to remember or carry with them.

Nowadays, there are many well known, already implemented methods of human identification (face, iris, retina, etc.), but still novel and innovative solutions are proposed and needed. Such situation is most apparent due to a large-scale biometrics problem, where even very successful methods fail in real-life security systems, such as access control in airports.

Therefore, to cover up for possible errors, other biometric modalities should be used, so that the overall accuracy and reliability of the hybrid systems is higher. Even though, these new emerging methods do not give results comparable with face or fingerprint systems, still such methods may improve accuracy of the hybrid systems, especially for people for whom standard systems fail to be effective.

Current trends in searching for novel modalities to identify humans are:

- 3D imaging (face, finger, ear),
- thermal imaging (face) and
- forensic science.

Some of the methods recently termed as "emerging" have now matured, to mention ear biometrics (motivated by forensic science) [1, 2].

Other new and emerging biometric modalities are [3–6]:

- human scent recognition,
- EEG biometrics,
- skin spectroscopy,
- knuckles texture,
- finger–veins and
- finger–nails recognition.

Some other person characteristics, such as moving or hipprints, are proposed to be used for soft authentication [7, 8].

Currently, new and unusual prints left in the crime-scene are taken into account by the police and forensic specialists.

Such novel procedures include earprints, noseprints, forehead-prints as well as shoeprints [9–11].

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One of the most interesting emerging method of human identification, which originates from the criminal and forensic practice (*cheiloscopy*), is human lips recognition [9].

The fact that lips features may be unique for humans have been confirmed by Yasuo Tsuchihasi and Kazuo Suzuki in their studies at Tokio University (1968–1971). They examined 1,364 subjects from 3 to 60 years of age of both genders. Their research proved that lips characteristics are unique and unchangeable (stable) for each examined person [9, 12].

In another research lip-prints have been used to support the sex determination of the examined subject [13].

Lip-prints characteristics have been also used in forensics experts and criminal police practice (Fig. 1). Such approach to human identity confirmation is used by the police and have been included as a subdiscipline of dactyloscopy.

Human lips features may be implemented in various scenarios, such as:

- speech recognition,
- multimodal audio–video speech recognition,
- speaker identification,
- multimodal audio–video speaker identification,
- lips reading and finally,
- lips based human identification based on the static mouth/face images.

In general, in accordance to the application scenario, lips features can be divided into three different categories:

1. lips texture features,
2. lips shape features,
3. lips motion features.

Hereby we consider human identification based on the static mouth/face images.

Using lips as modality for human identification has the following advantages:

1. Lips biometrics is passive biometrics—user/subject interaction is not needed. Images may be acquired from the distance without the knowledge of the examined person.
2. Lips biometrics is anatomical—better results are expected than in behavioral biometrics.
3. Lips are usually visible—not hidden/overcast by anything.
4. Lips may be implemented in hybrid lips-face or lips-voice biometric systems.

In our approach we calculate color features of the masked out lips and we merge them with shape features of the binarized lips. We calculate color statistics and moments as well as a set of standard geometrical parameters and the moments of Hu and Zernike.

Furthermore, we developed original geometrical parameters dedicated to biometrics based on human lips.

In Sect. 2 related research developments are briefly overviewed. In Sect. 3 our algorithm for lips detection with sample results is presented. Shape and color feature extraction methods are described in Sects. 4 and 5. Original shape features developed for lips biometrics are proposed in Sect. 4.1.

Experimental results, future work and conclusions are given thereafter.

2 Related work

While manually examining human lips characteristics, most often, the anatomical patterns on the lips are taken into account. For example, the pioneer of *cheiloscopy*, professor J. Kasprzak defined 23 lips patterns [9]. Such patterns (lines, bifurcations, bridges, pentagons, dots, lakes, crossings, triangles etc.) are similar to fingerprint, iris or palmprint patterns.

The listed patterns of human lips have been available at http://www.kryminalistyka.fr.pl/crime_cheiloskopia.php.

The sample patterns are presented in Fig. 2.

However, in biometric systems based on image analysis techniques, such line-topology features cannot be used since it is hard to extract them from acquired images.

Therefore, in our approach we do not use lip-prints features, but we focus on characteristics extracted from lips/face images. Such images can be acquired from a

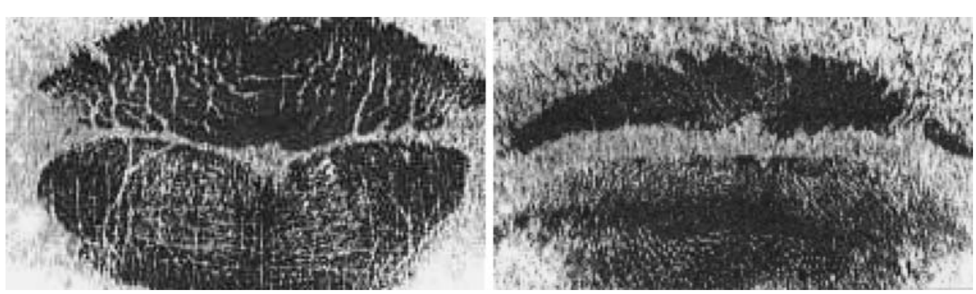

Fig. 1 Lip-prints samples used in forensic evidence expertise [9]

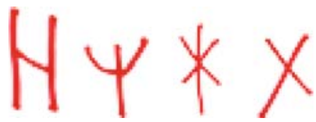

Fig. 2 Sample lips line-topology patterns [14]

certain distance by a standard camera in controlled or uncontrolled environment.

Automated lips biometrics have not been extensively researched so far, but there are some published approaches to human lips feature extraction.

Gomez et al. achieved some very promising results using geometrical parameters, HMM and PCA methods [15]. They reported 96.2% recognition rate on a database of 500 images (50 subjects with 10 images per person).

Cetingul et al. proposed to explore 2d-DCT coefficients as lips texture features and used them in multimodal speaker/speech recognition system [16].

They also developed eight lips shape parameters based on the lips geometry. The maximum horizontal distance and the 7 vertical distances (from the Cupid's bow to the lower lips boundary characteristic points) are calculated (Fig. 4) [17].

3 Lips detection

In the first step lips are detected from face images. Then we perform segmentation, binarization and size

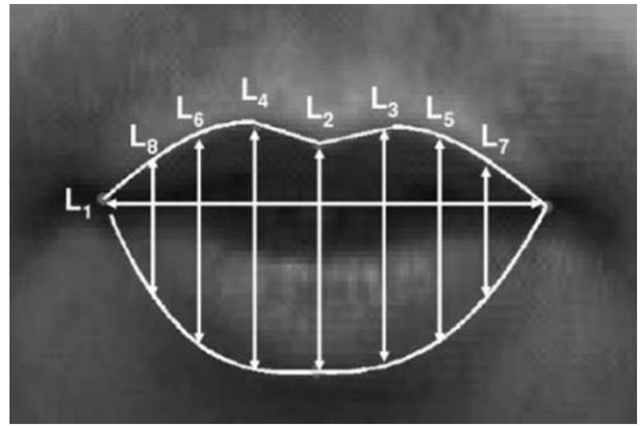

Fig. 4 Lips shape parameters proposed by Cetingul et al. [4]

normalization. Most of known lips detection methods proposed so far, had been designed for speech recognition and tracking [4, 18–21].

We modified a method based on color discriminates proposed by Kubanek [22, 23].

In our case color discriminates are calculated not only in the *RGB* space, but in the *HSV* and *YUV* color spaces as well.

After experiments, we may conclude that the best results of lips detection were achieved in the *HSV* color space.

The condition for lips detection is presented in Eq. 1.

Fig. 3 Sample lower face images from our database (three images of the same person)

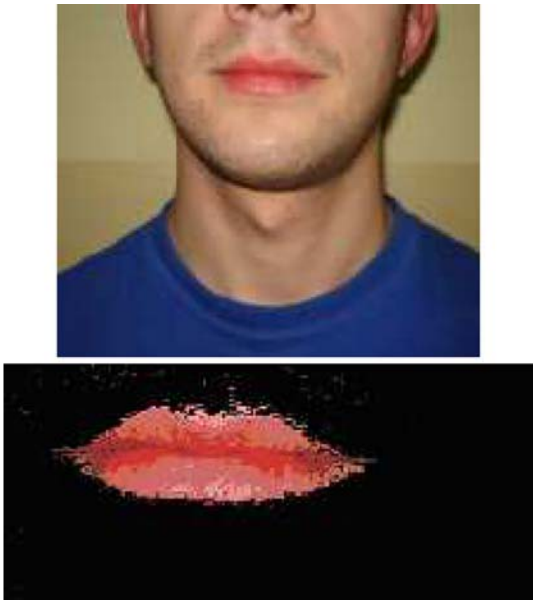

Fig. 5 Example of lower face and extracted corresponding lips area

$$\begin{cases} H \geq 334 \vee H \leq 10 \\ S \leq 25 \end{cases} \tag{1}$$

The sample results of our lips detection algorithm from lower face images are presented in Figs. 5 and 6.

So far our algorithms work well for face images captured especially for lips recognition project (lower face only). Unfortunately, we struggle with satisfactory lips detection on other datasets, especially face images from surveillance cameras.

4 Lips shape feature extraction

After lips detection stage, shape features of the binarized lips images (Fig. 6) are calculated.

We decided to calculate geometrical parameters of detected lips area. We calculated moments of [24, 25]:

- central moments
- Zernike moments
- Hu moments.

Moreover we used standard geometrical shape parameters to describe human lips:

- Malinowska ratio
- Feret ratio
- Blair-Bliss ratio
- Danielsson ratio
- Haralick ratio
- Lp1 ratio
- Lp2 ratio.

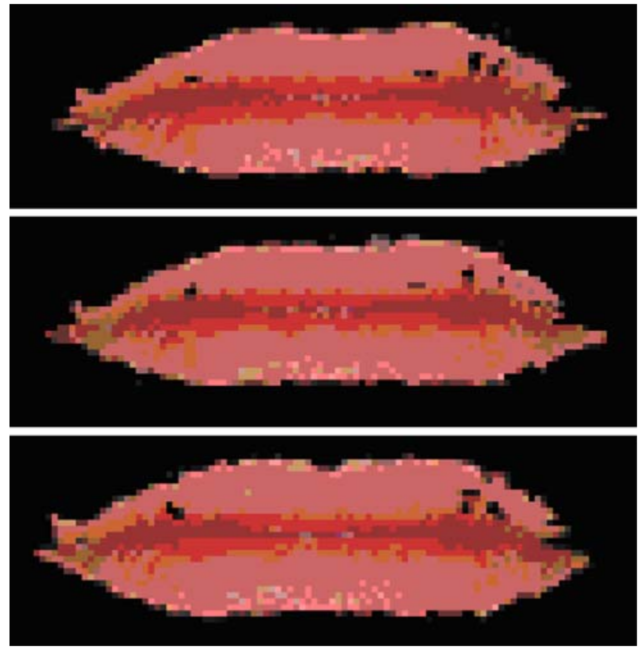

Fig. 6 Examples of extracted lips shapes from face images

4.1 Original lips shape parameters

Furthermore, we added our own original parameters developed for the lips biometrics.

9 novel parameters, developed especially for lips biometrics and describing lips shape are as follows:

1. lips width to perimeter ratio WO given by: $WO = W/O$ where W is the lips width and O is lips perimeter, as presented in Fig. 7.
2. Upper to lower lips height ratio ULH given by: $ULH = H1/H2$ where $H1$ is the upper lip height calculated in the middle column of the lips, and $H2$ is the lower lip height calculated in the middle column of the lips (Fig. 8).
3. Upper lip height to width ratio ULW given by: $ULW = H1/W$ where $H1$ is the upper lip height

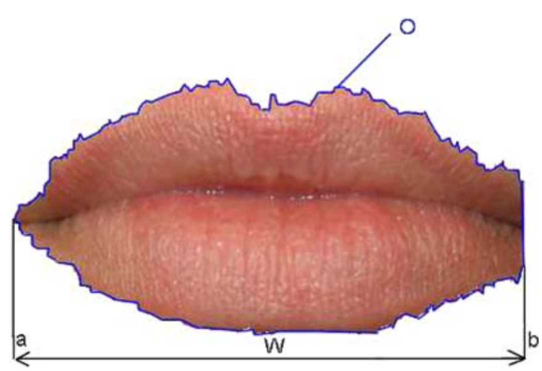

Fig. 7 Lips width to perimeter ratio

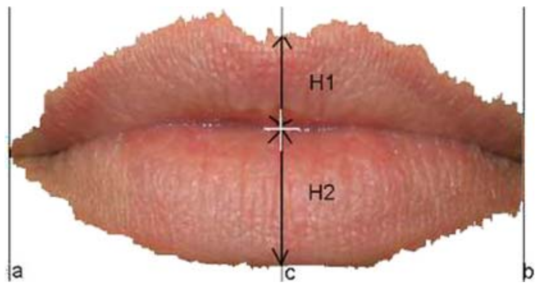

Fig. 8 Upper to lower lips height ratio

calculated in the middle column of the lips and W is the lips width (Fig. 9).

4. Lower lip height to width ratio LLW given by: $LLW = H2/W$ where $H2$ is the upper lip height calculated in the middle column of the lips and W is the lips width (Fig. 10).
5. Inner to outer circle ratio $C2C$ given by: $C2C = pk/PK$ where pk is the inner circle and PK is the outer circle as shown in Fig. 11.
6. Width to middle height ratio WMH given by: $WMH = W/(H1 + H2)$ as presented in Fig. 12.
7. Left side upper to lower lip convexity ratio LC given by: $LC = m1/m2$ where $m1$ is the upper lip left side convexity and $m2$ is lower lip left side convexity as presented in Fig. 13.
8. Right side upper to lower lip convexity ratio RC given by: $RC = n1/n2$ where $n1$ is the upper lip left side convexity and $n2$ is lower lip left side convexity as presented in Fig. 14.
9. Indent ratio IR given by: $IR = H3/H$ where H is the lips height and $H3$ is the height of the indent calculated according to the Fig. 15.

5 Lips color features

We calculate statistical color features in three types of color spaces: RGB, HSV and YUV. Features are calculated

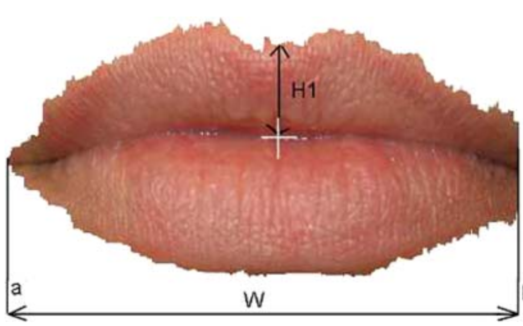

Fig. 9 Upper lip height to width ratio

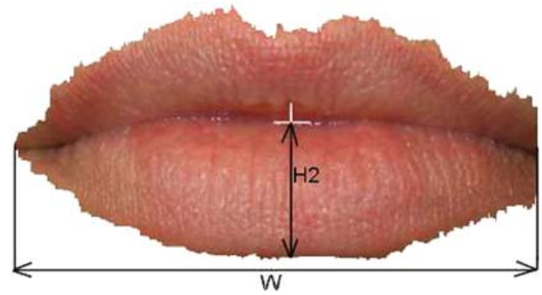

Fig. 10 Lower lip height to width ratio

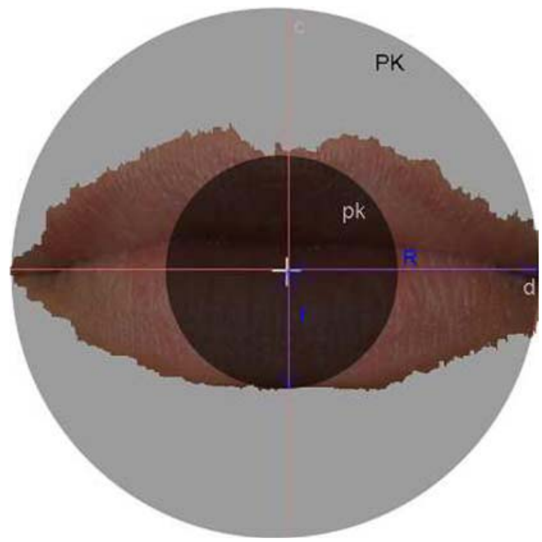

Fig. 11 Inner to outer circle ratio

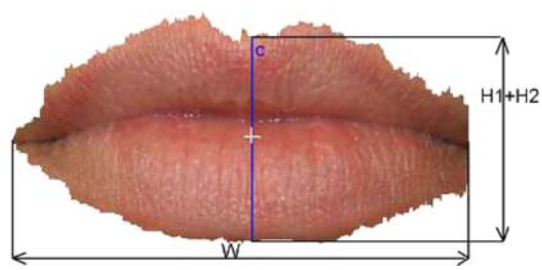

Fig. 12 Width to middle height ratio

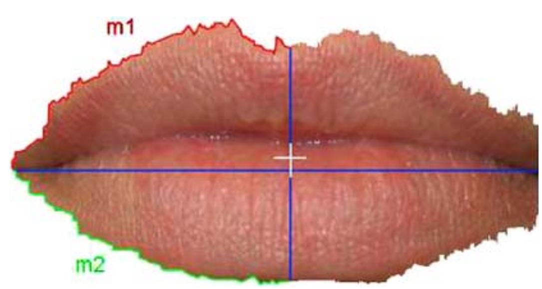

Fig. 13 Left side upper to lower lip convexity ratio

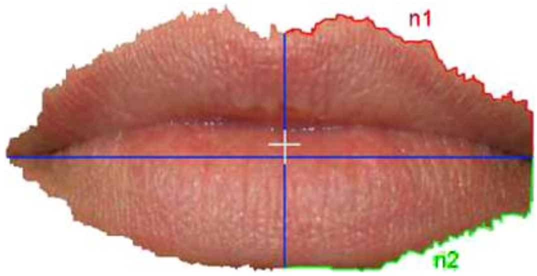

Fig. 14 Right side upper to lower lip convexity ratio

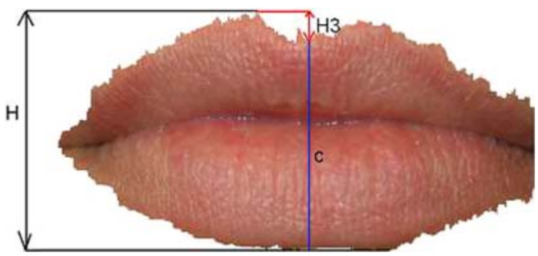

Fig. 15 Indent ratio

separately for each channel in the used color spaces. Moreover, we use the *MONO* channel of the monochromatic image.

Color feature vector consists of the following features:

- maximum density—number of pixels of the most common intensity in the image
- minimum density—number of pixels of the least common intensity in the image
- mean given by:

$$m_i = \frac{1}{N}\sum_{j=1}^{N} p_{ij} \tag{2}$$

where i and j are the pixel coordinates
- variance given by:

$$\sigma_i = \left(\frac{1}{N}\sum_{j=1}^{N}(p_{ij} - m_i)^2\right)^{\frac{1}{2}} \tag{3}$$

where i and j are the pixel coordinates
- slantity given by:

$$s_i = \left(\frac{1}{N}\sum_{j=1}^{N}(p_{ij} - m_i)^3\right)^{\frac{1}{3}}. \tag{4}$$

Calculated lips color features in specific color spaces are presented in Fig. 16.

Some features are not calculated within certain color spaces (marked with the dash).

	COLOR CHANNEL									
	R	G	B	MONO	H	S	V	Y	U	V
Max density	1	5	9	12	16	20	24	-	-	-
Min. density	-	-	-	14	-	-	-	-	-	-
Mean	2	6	10	15	17	21	25	28	30	32
Variance	3	7	11	-	18	22	26	29	31	33
Slant	4	8	12	-	19	23	27	-	-	-

Fig. 16 The chart presenting calculated lips color features in specific color spaces. Each calculated color feature is *numbered*. If the feature is not calculated in a given space it is marked with the *dash*

6 Feature selection and experimental results

In the experiments, we used our own database of lower face images. We acquired 3 images per person. The lips database used in our experiments consists of 3 images from 38 people (114 images).

The feature vector describing lips consists of: geometrical parameters, Hu moments, central moments, moments of Zernike, statistical color features in *RGB*, *YUV* and *HSV* color spaces. After feature extraction step we performed feature selection. After experiments we chose most discriminative and effective features.

After experiments and evaluation it turned out that adding novel geometrical parameters to the feature vector increased system efficiency (in comparison to our previous work [26, 27]).

Human lips recognition results without and with the novel developed geometrical parameters are shown in the Table 1.

So far we have achieved the recognition rate (Rank-1) of 82%.

The ROC curve of our lips biometric system is presented in Fig. 17.

The CMC curve describing our system is presented in Fig. 18. The Rank-4 and Rank-5 recognition rate increased up to 86%.

7 Future work

At this moment we work on using symmetry as a feature which may help to better describe human lips.

We use horizontal and vertical symmetry to obtain two symmetrical images and two ‘delta’ images (difference between the originally acquired subject’s image and corresponding symmetry images).

Sample original, horizontal and vertical lips contour images are presented in Fig. 19.

Table 1 Lips Rank-1 recognition rate results

Method	Number of tests	Correct acceptances	False rejections	Rank-1 (%)
Lips features	76	58	18	76
Lips features with novel parameters	76	62	14	82

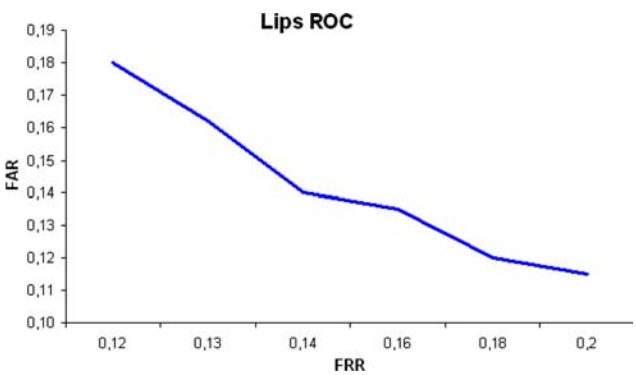

Fig. 17 ROC curve of lips biometric system

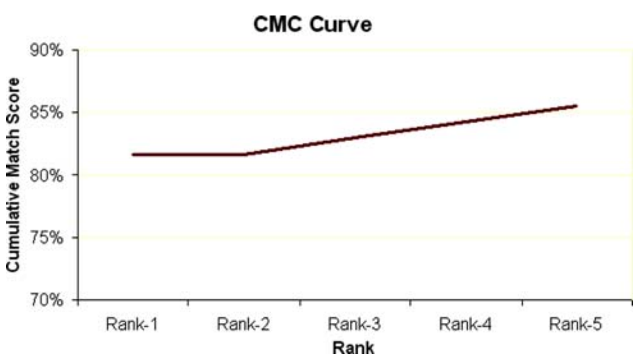

Fig. 18 CMC curve of lips biometric system

Fig. 19 Sample original and corresponding symmetry lips images

Now we work on selecting efficient features from symmetry and 'delta' images. We also plan to use discrete symmetry transform to find lips *fiducial* points to which Gabor Jets may be applied [28–30].

8 Conclusions

In this paper we presented feature extraction methods and introductory results of automated human lips biometric system. In our research integrated lips shape descriptors and color features had been used to determine human identity.

So far the major problem of our system is the lips detection step. We detect lips easily from face images captured especially for lips recognition project (lower face only). Unfortunately, we struggle with satisfactory lips detection on other datasets, especially face images from surveillance cameras.

However, we have achieved promising recognition results for well detected lips images, which motivate our further research in this area.

We plan to extend our research with the development of new lips features. We are investigating the texture and symmetry features of the human lips. Moreover, we try to improve the lips detection algorithm with the Active Shape Models approach.

Lips biometrics could be used to enhance effectiveness of other well-known biometrics, by its implementation in multimodal systems. Since most of the methods have some drawbacks, the idea of building multimodal (hybrid) biometric systems is gaining lot of attention [31].

Lips biometrics seems to be a natural choice to support well known methods like voice and face recognition in emerging applications such as access control, border security and recognition for human-vehicle interaction [32].

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