Lip Print : An Emerging Biometrics Technology – A Review

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***Abstract*— Biometrics is often referred to a metric related to human features and characteristics. When utilized for authentication and verification purpose, a live biometric is compared against a stored template of enrolled users to produce a match. Most popularly used biometric technologies are fingerprints based identification, face recognition, voice/speech recognition, iris recognition and so on. Research shows that lip-imprints are one of a kind to every person and they don't change during their entire life time. Like other biometrics, lip-prints can also be used as a tool to effectively identify a person. Identifying a person through lip prints is termed as Cheiloscopy. Cheiloscopy is slowly gaining popularity throughout the world. However, very little work is done on lip-prints based identification so far. The aim of this review work is to identify various techniques to use lip-prints as a biometric and also to determine the drawbacks of the existing techniques in terms of complexity, scalability and efficiency. The comparative analysis of the identified techniques is presented as the outcome of this survey. The related work and the scope for future research in this context is also discussed.**

Keywords—Lip-prints; Cheiloscopy; Biometrics; Machine Learning; Image Processing

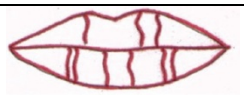
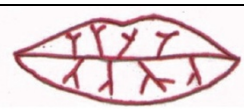
I. INTRODUCTION

Identification of a person has always been a challenging task for scientists. It is necessary for all legal, personal and social reasons. Dental data, DNA, fingerprints are the most popularly used identification methods. The emerging technology or tool for human identification is Cheiloscopy. Cheiloscopy is the study of lip prints or traces that helps to uniquely identify a person. Since 1950's, Japanese researchers have performed exhaustive study on lip-prints. In early 1970's, two Japanese scientists named T. Suzuki and Y.Tsuchihashi analysed the lip-prints of 1364 individuals and inferred that lip-prints are unique for an individual. They also established a possibility of utilizing lip-prints in personal identification. They classified the lip-prints into 6 categories based on the patterns found. The classification and their description is shown in Table I.

Lip prints can be acquired using various methods. Some of them include application of colouring agents like lipsticks on the lips and asking the subject to press his/her lips on a piece of paper or cellophane tape, photographing an individual's lips or using any fingerprint developing techniques [20]. There are no many publicly available database of lip-print images. The ones that are available freely to the public for research purposes are SUT-Lips-DB database and lip prints provided by The Biometric Research Centre, University of Silesia.

Lip-prints are the natural lines forming ridges and depressions on the human lips. They are unique alike the fingerprints. It has been confirmed that lip prints recoup in the wake of experiencing changes, for example, minor injury, irritation and so on. However major injuries may leave behind scars that lead to the altering of the patterns.

TABLE I. T. SUZUKI AND Y. TSUCHIHASHI CLASSIFICATION

Type of Lip-print	Figure	Description
Type I		Complete straight grooves
Type I'		Partial straight grooves
Type II		Branched grooves
Type III		Intersected grooves
Type IV		Reticular grooves
Type V		Other pattern

Lip-print based identification systems are mainly used to identify a person by matching the lip-prints. Most of them initially pre-process the lip prints, extracts the patterns, train the system, verifies a new lip-print using the trained system and analyse the accuracy. Lip prints are either analysed manually or using automated computer algorithms. Manual methods involve manually identifying the lip print patterns

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and classifying them. Tools like magnifying glasses and scales are used to manually analyse the lip-imprints. They are mostly used in forensic odontology. Manual methods are prone to human errors. Automated methods use various image processing techniques, machine learning algorithms and statistical approaches that may not adapt to anything beyond the algorithm's scope. They involve pre-processing of acquired digital images to enhance the quality and remove noise. Patterns are then extracted and classified using various machine learning algorithms [19]. Automated methods yield better results when compared to the manual methods. Over the years, considerable amount of research is done on segmentation of lip-prints as well as pattern extraction using various image processing techniques and machine learning algorithms.

Lip-prints can also be used as an aid in crime investigations. Many cases have been solved using lip-prints as a piece of evidence. Notable ones are the Virginia peeping Tom case where the suspect was caught using the lip-prints left on the woman's window and the Illinois murder case where the murderer was arrested on the basis of lip-print found on the duct tape in the crime scene.

In this paper, Section II discusses the Related Works and Section III highlights the challenges. Conclusion is discussed in Section IV.

II. LITERATURE REVIEW

Lukasz Smacki et al. proposed a method for recognizing the lip prints using DTW (Dynamic Time Warping) algorithm. The proposed method had 2 stages. First stage was pre-processing of the lip print images and second stage was feature extraction. The proposed method was tested using lip prints of 30 people. Results obtained were satisfactory and the author stated that it can be used effectively in the forensic labs. Author also stated that further modification to the DTW algorithm would result in higher accuracy[1].

Lukasz Smacki proposed a method of analyzing lip prints using Fast Normalized Cross-Correlation technique. Firstly images were standardized removing the background. Once the background is removed, the images are split to differentiate the upper lip and lower lip. After the splitting is done, they are aligned horizontally. In order to highlight the patterns and lines on the lip prints, feature extraction is done. This study was conducted using 300 images. Test was conducted on full lip images as well as their sub images. Higher accuracy was obtained with sub images. The study ignored the distorted and blur lip print images[2].

Renjith George et al. conducted a study on Malay population. The main aim of this study was to determine if there was any resemblance in the lip patterns of the family members. 124 lip prints from 31 families that consisted of a mother, father and 2 children were considered. They were classified based on the standard Tsuchihashi's classification. The patterns were analyzed using Karl-Pearson Correlation Co-efficient approach. Results showed that type I pattern was predominant among the Malay population. It also showed that 58.06% of the lip prints showed the resemblance between the parents and the children. The authors stated that larger samples can be used to confirm the results further[9].

Krzysztof Wrobel et al. proposed a technique for recognition of lip-print images based on section comparison. Here sections referred to the lines or patterns present on the lips. Section extraction was done using Hough Transform method and then an algorithm was devised to compare the sections. Test was conducted on 45 lip images. Based on the length of the extracted sections, error rate was calculated. It was observed that section length greater than 30 resulted in high error rates [3].

Saptarshi Bhattacharjee et al. proposed an approach to identify individuals from lip prints using a Statistical Model. Fast Match and Accurate Match algorithms were used for the stated purpose. Feature vectors were calculated and Euclidean distance was used as measure to calculate the distance between the feature matrices for matching of lip-prints. 20 images were considered for the study. Accurate Match algorithm yielded higher accuracy over Fast Match algorithm. Accuracy can be further improved using larger samples[4].

Pawan Sharma et al. proposed a method for lip print recognition that can be utilized for personal identification. Firstly the images were acquired. The acquired images were pre-processed to remove unwanted noise. Patterns extracted during the feature extraction phase were used for the matching purpose. Brute Force algorithm was used for matching the patterns. 200 images were used for the study. The accuracy obtained was 89.5%. This study ignored the complexities like change in lip prints due to various factors like scarring, aging etc[5].

Jin Ok Kim et al. proposed an approach for lip print recognition using Multi-resolution architecture. It overcomes the shortcomings of single-resolution architecture. It converts the information obtained from the lip-prints into digital format. Lip prints obtained from 24 individuals were used for the study. This study yielded an accuracy of 85% with single-resolution architecture based system and 90.6% with 2 single-resolution architecture based systems and 95.3% with 3 single-resolution architecture based systems[6].

Michal Choras upheld the idea of using lip prints for identification of individuals. Firstly the lips were detected from the face images using a method based on color discriminates. Next, the features were extracted calculating the geometrical parameters. Color features were calculated in RGB, HSV and YUV color spaces. Most effective features were selected after the feature selection phase. This method yielded an accuracy of 82%. Author further stated that the lip detection phase could be further improved to get better efficiency and results[7].

L.H. Adamu et al. conducted a study in Kaduna, North eastern part of Nigeria. It included lip prints collected from 820 individuals. People with any kind of deformities related to lips were excluded from this study. For the analysis, upper lip and lower lip were divided into 5 compartments each. Each and every compartment was analyzed using Pearson's Chi-squared test. Results showed the predominant patterns found in different groups of people. People belonging to Hausa,

Yoruba and Igbo sect had Type V pattern as the predominant one[8].

Neeti Kapoor et al. conducted a study on Marathi inhabitants to analyze the lip-print patterns. The study considered lip prints obtained from 200 individuals of which 100 were males and 100 were females. Lip prints were obtained through digital photography. The lip prints were classified using Suzuki and Tsuchihashi's classification. The lip prints are divided into 4 compartments and analyzed using Chi-squared test. Results showed that type I pattern was predominantly found among Marathi population. Same test was conducted after about 6 months and the lip prints were found to be stable over a period of 6 months[10].

Ryszard S. Choras proposed a method of using lip prints as biometrics. The paper highlighted lip feature extraction based on Radon transform and steerable filters. Before feature extraction is carried out, the images were pre-processed. Euclidean distance was used to calculate the similarity measures. The study considered 64 lip print images. The author states that the method proposed is good enough to be used in forensic systems and investigations[11].

Piotr Porwik et al. proposed a technique for recognition and comparison of lip prints using DTW algorithm and the Copeland vote counting approach. DTW algorithm is used to calculate the similarity between the lip patterns. The results obtained were satisfactory and the level of recognition was poor. In order to refine the accuracy DTW algorithm was paired with the Copeland vote counting approach where an unknown object is classified based on pair wise contest Condorcet's vote counting method. 120 lip prints were used for the study. Author states that this approach can be used in forensic cases effectively[12].

L. Smacki et al. proposed a new approach for lip print pattern extraction. The presented approach consisted of 2 stages. Segmentation and pattern extraction. Segmentation was done by converting the original image into gray scale image and then merging the luminosity and entropy images into a single image. Finally thresholding was done using Otsu's method. In the pattern extraction stage, the quality of the image was improved by smoothing techniques and top-hat transform is applied on the resulting image. The proposed method improved the accuracy of identification greatly. 300 lip prints of 50 individuals were considered for the study[13].

Deepa Jatti et al. conducted a study on South Indian population to analyze their lip-prints and determine the similarities and differences. 150 samples were considered for the study. These samples were obtained using adhesive tapes and lipstick. Prints were analyzed using Adobe Photoshop software. The prints were further classified using Suzuki's classification. Coimbatore population was mainly considered for this study. Results showed that type II pattern was predominant among the Coimbatore individuals followed by type I[16].

Shobha Channabasappa Bijjargi et al. conducted a study to compare the lip prints of different race groups. Tibetans, Kodavas and Keralites were considered for the study. Total of 600 lip-imprints were considered for the study. They were divided into compartments using Adobe Photoshop software C5 and was analyzed for similarities using Chi-square test. Lip prints were collected manually from the individuals. The results showed that type I pattern was mostly found in Kodavas, type II pattern was predominant among Keralites and type III pattern was predominant among Tibetans. Since no two individuals had same lip print pattern, the author stated that lip prints can be used for race identification as well. The only problem faced during the study was manual collection of lip prints[14].

Mercedes Alvarez Segui et al. stated that presence of the lipstick print on an accused person's clothing can be used as an evidence in the crime investigations. The study aimed at presenting lip print test results using permanent lip sticks. Four permanent lipsticks were used for the study. Developing the lip-print doesn't require any special method. It is same as in the case of fingerprints. The only distinction would be that lip- prints are found on those sites or materials where lips are likely to be placed. Tests were conducted using cobalt oxide powder, aluminium powder and magnetic powder as developers. Magnetic powder and aluminium powder provided best results. The author said that lip prints can be an important piece of evidence in crime investigations that cannot be ignored[15].

Vikas Ranjan et al. conducted a study to identify a human and the gender based on the lip-prints. Pearson's chi-squared test was used for the analysis purpose.300 lip print images were considered for the study. The subjects with abnormalities related to the lips were excluded from the study. Both the upper and lower lip portion was used for the study. Lip prints were manually collected from the volunteers using lipsticks. The lip-prints were analyzed and further classified. Similarities and dissimilarities were analyzed using statistical methods. Results showed that type I pattern was predominant with an accuracy rate of 83.4%[17].

Krzysztof Wrobel et al. proposed a method for identification of a person based on lip-prints. It mainly concentrated on bifurcations found on the lips. Bifurcations are extracted analyzing all the black pixels on the lip print images. Identification was done comparing the resultant bifurcation matrices obtained. The result of this comparison yielded a similarity measure. Lower the similarity measure, more similar the lip prints were. 120 lip prints were considered for the study. The best result achieved had an Error rate of 23%[18].

TABLE II. OVERVIEW OF LIP PRINT BASED IDENTIFICATION TECHNIQUES

Authors[Ref]	Techniques Used	No. of Sample Images	Key findings
Lukasz Smacki et. al [1]	DTW algorithm	30	Results obtained demonstrated the possibility of using lip-imprints in forensic studies.
Lukasz Smacki [2]	Normalized Cross-Correlation technique	300	Performance was improved when lip-print images were divided into sub-images.

Krzysztof Wrobel et al.[3]	Hough Transform method	45	Section length greater than 30 resulted in higher error rates.
Saptarshi Bhattacharjee et al. [4]	Statistical approach	20	Accuracy could be enhanced using a larger sample size.
Pawan Sharma et al[5]	Brute force algorithm	200	Quality of the images used would affect the accuracy.
Jin Ok Kim et al [6]	Multi-resolution system	24	Multi-resolution systems reduced the error rates.
Michal Choras [7]	Geometric parameter based technique	114	Detecting lips from the human face was a challenging task.
L.H. Adamu et al.[8]	Pearson's Chi-squared test	820	Type V pattern was found to be predominant among Nigerians.
Renjith George et al. [9]	Karl-Pearson Correlation Co-efficient approach	124	Type I pattern was found to be predominant among Malay population.
Neeti Kapoor et al. [10]	Pearson's Chi-squared test	200	Type I pattern was found to be predominant among Marathi population.
Ryszard S. Choras [11]	Radon transform technique	64	Results obtained demonstrated the possibility of using lip-imprints in biometric systems.
Piotr Porwik et al. [12]	DTW algorithm and Copeland vote counting approach	120	Results suggested that if lip imprints features are captured properly, they can be effectively used in forensic studies.
L. Smacki et al. [13]	Otsu's method and Top hat transform technique	300	Using Top-hat transform for feature extraction yielded satisfactory results
Shobha Channabasappa Bijjargi et al [14]	Pearson's Chi-squared test	600	Type I pattern was predominant among Kodavas, type II pattern was predominant among Keralites and type III pattern was predominant among Tibetans.
Mercedes Alvarez Segui et al. [15]	Manual approach	24	Using Magnetic powder and aluminium powder as developers provided best results.
Deepa Jatti et al. [16]	Manual approach	150	Type II pattern was predominant among the Coimbatore individuals.
Vikas Ranjan et al. [17]	Statistical approach	300	Type I pattern was predominant with an accuracy rate of 83.4%
Krzysztof Wrobel et al. [18]	Bifurcations analysis	120	Extracting bifurcations was a challenging task. The best result achieved had an Error rate of 23%.

III. CHALLENGES

The methods employed to acquire the lip-prints and the methods for matching them are disparate for different approaches but the main aim is to analyse the patterns found on the lips. Lip-prints can either be acquired manually or can be represented as digital images [19]. The major challenge in commercializing lip-print based identification is the method of lip-print acquisition. There is no gold standard to obtain the lip-prints. Various research works advocate different techniques like photographing the lips, using lip-sticks or other colouring agents, usage of finger printer in order to acquire the lip-prints. Smudging of the lip-imprints due to presence of facial hair in men, pressure direction, amount of the colouring agent used are also the challenges that needs to be taken into consideration. A standard and uniform methodology to acquire lip-prints needs to be developed [20]. Once the lip-prints are acquired, they can be effectively used as biometrics in commercial applications. It can further be helpful in crime investigations and forensic sciences as well.

IV. CONCLUSION

This paper presents an overview of the techniques that can be employed to use lip-prints as a tool for personal identification. Most of the techniques begin with image pre-processing as the initial step followed by feature extraction and Identification/Verification. Manual methods were time consuming and had a possibility of human errors. Automated methods using DTW algorithm, Top-Hat Transform algorithm, Vote counting methods and Hough Transform methods proved to be efficient. Large number of research articles stated that the overall accuracy depends on the sample size considered for the study, hence using large number of images could further increase the efficiency. Many studies proved that the patterns found on the lip prints can serve as an aid in gender determination as well. Using efficient image pre-processing, segmentation, feature extraction and classification techniques to further improve the accuracy of the existing systems is a part of our future work.

Alongside other customary methods, Cheiloscopy can serve as an aid for person identification. Standard methods needs to be produced for acquiring and recording the lip-imprints. Since a great deal of research is taking place globally in this direction, very soon lip-prints will be used as a popular biometrics technology in every field.

Collectively, this work emphasizes the need to develop a robust computer aided system for lip-print based personal identification that would work across various datasets to provide desired outcomes.

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