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Lip-Prints Analysis with a Technical Approach of MATLAB

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ABSTRACT

Lip prints, often found at crime scenes, might provide a direct link between the victim and the offender. Everybody has unique ridge patterns in their lip prints, which are useful for identification. In this work, we compared these unique patterns using a histogram-based approach on 250 lip prints. To measure the degree of similarity between the histograms of various lip prints, we used Bhattacharyya distance, Chi-square tests, correlation coefficients, and pixel intensity distribution throughout the lip prints. Our findings supported the idea that each person's lip print is distinct as no two histograms matched exactly (100% similarity), even if some of them displayed some shared general traits.

INTRODUCTION:

Cheiloscopy is the scientific study of the different grooves and creases that can be seen on the labial mucosa. These are the cells that are found between the outer ectodermal tissue of the lip and the inner labial mucosa. Their name is derived from the Greek words for wrinkles and grooves. Anthropologists first noticed the biological occurrence of networks of furrows on the red portion of human lips; R. Fischer was the first to describe it in 1902.(Kasprzak, 1990) The thought of using a person's lip print for authentication and identification was initially put forth by Synder in 1950. He had investigated a traffic accident and demonstrated that the features of lips created by lip grooves are just as uniquely distinctive

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as the ridge features of fingerprints. (Vamsi & Reddy, 2011) But prior to 1950, anthropology didn't offer a useful explanation for the anomaly; it only acknowledged that the furrows existed. The Japanese have done a great deal of study on the subject since 1950. Two Japanese researchers, T. Suzuki and Y. Tsuchihashi, worked together from 1968 to 1971.(Tsuchihashi, 1974a) They classified lip prints for the first time. The Tsuchihashis classification, which Suzuki and Tsuchihashi proposed in 1970, is the most often used categorization in literature. Lip prints are particularly helpful for forensic analysis and identity verification. (Arofi Kurniawan, 2023) They are comparable to fingerprints and are thought to be the most significant kind of transfer evidence. Lip prints, which are frequently left at crime scenes, can establish a clear connection to the perpetrator. In recent years, lipsticks have been created that, when applied on surfaces like glass, fabric, flatware, or cigarette butts, leave no visible traces. These lip prints are referred to as "permanent" lip prints since they are distinguished by their durability. Despite being undetectable, these prints can be removed using substances like aluminum powder and magnetic powder.

The classification schemes for lip prints put out up to this point were based on the general form of the creases and grooves found on the lips. However, the objective of this investigation was to based on the inclination, orientation, numerical supremacy, and co-existence of various forms of lip print prototypes, differentiate lip prints. An effort has been undertaken to develop a different, all-inclusive taxonomy to categories the lip prints. In addition, to thoroughly examine every area of the lip, the Klein's zone has been divided into 10 quadrants in this study, with four on the top lip and the remaining four on the lower lip. This method is anticipated to successfully identify a person, even if only a tiny portion of the lips is affected by smoking, chewing tobacco, any pathological condition, or a fragmented or incomplete print found at the crime scene. The focus has been on confirming whether the lip print patterns present in each quadrant differ in any way and to determine whether each pattern appears alone or in conjunction with other patterns.(Kaur & Thakar, 2021)

Forensic dentistry's goal is to use dental evidence to analyses and assess objective scientific facts for use in court cases.(Krishan et al., 2015) Additionally, forensic dentists need to be knowledgeable in a variety of fields since dental records can be used to identify a person or to demonstrate neglect, fraud, or abuse by the authorities.

In any criminal inquiry, identification is a crucial factor. The identity of the person is the definition of personal identification. Establishing whether a personal identity attribute belongs to a specific human or not is the first step in achieving personal identification. In cases of amnesia, unconsciousness, imposters, issuance of identity cards, passports, driving licenses, legal documents, etc., personal identification is crucial. With the advancement of science, human traits like as fingerprints, DNA, iris patterns, lip prints, and dental structures are now used for identification. They are typically utilized for personal identification in forensic science. The majority of the DNA and fingerprints from crime scenes are discovered as proof.

MATERIALS AND METHODOLOGY:

A pilot study involving 250 subjects aged between 19 and 28 years was conducted at the Department of Forensic Science and Biochemistry, Gujarat University, Ahmedabad, India. Participants with lip-related conditions such as inflammation, ulcers, trauma, congenital developmental defects, deformities, and surgical scars were excluded to maintain the integrity of the data. Informed consent was obtained from all subjects who were informed about their participation in the research.

Special attention was given to cleanliness and hygiene due to the involvement of the human mouth in the study. The procedure began by demarcating the lip boundaries using a red-colored lip liner to ensure the lipstick application remained within the designated area. The lip liner was sanitized after each use to prevent cross-contamination. Lipstick was then systematically applied with a brush to avoid smudging, starting with the upper lip. After allowing 30 seconds for the lipstick to dry, a lip print was collected using 14-mm wide and 50-mm long Scotch tape, applied with gentle pressure. The tape was then affixed to a plain white A4 bond paper, labeled with the subject's serial number, name, and date. This process was repeated for the lower lip. Additionally, lip prints of both the upper and lower lips were recorded simultaneously using a 50 mm wide and 50 mm long Cellophane tape to confirm the alignment of the midline. Post-recording, the lips were cleaned with a cleansing agent.

The used lipstick brushes underwent a stringent cleaning process, being washed with water and soaked in a 0.5% Sodium Hypochlorite solution for 30 minutes, followed by another rinse with water.

For photographic documentation of the lip prints, a bespoke imaging setup was employed. This setup consisted of a box constructed from 1 cm thick PVC sheets, each measuring 20x20 cm. The interior of the box was outfitted with two 2-watt LED lights, which were connected to a power source through a wire and controlled by an external switch. The box was enclosed to minimize light dispersion, ensuring uniform illumination. Lip prints were placed inside this controlled environment, and photographs were captured using a Canon 700D camera. Initially recorded in JPG format, the images were subsequently converted to PNG format for compatibility with MATLAB, which does not process JPG files.

Within MATLAB, these PNG images were first converted to grayscale to facilitate the differentiation of black and white matter, an essential step for analyzing the fine details in the lip prints. The grayscale images were then further processed into binary images by segmenting them into four quadrants. This segmentation allowed for a detailed examination of the color distribution within each image. Following this, the binary images were analyzed to generate histograms representing the color frequency distribution of the data set, with each histogram being unique to its corresponding image.

This methodical approach to image processing was standardized across all samples to ensure consistency. For the comparison of histograms, Python software was utilized due to its robust data handling and analysis capabilities. To compare two histograms (H1 and H2), a suitable metric (d(H1,H2)) was selected from several options including correlation, Chi-Square, intersection, and Bhattacharyya distance. These metrics provided a quantitative measure of similarity between the histograms, which is crucial for identifying and analyzing patterns across different lip print images.

For the quantitative analysis and comparison of lip print images in our study, we utilized various histogram matching techniques to assess the similarity between different samples. These methods are essential for forensic and diagnostic applications where precise pattern recognition and comparison are required. We employed the following histogram comparison metrics:

1. Correlation (CV_COMP_CORREL): This method assesses the degree to which two histograms are correlated. The correlation coefficient, (D(H_1, H_2)\), is defined as:

$$D(H1,H2)=\sum I(H1(I)-H1)2\sum I(H2(I)-H2)2\sum I(H1(I)-H1)(H2(I)-H2)$$

where H1, and H2 are histograms, N is the total number of histogram bins. This metric indicates the extent to which the changes in one histogram are linearly related to changes in another.

2. Chi-Square (CV_COMP_CHISQR): The Chi-Square distance, (d(H_1, H_2)), is calculated as follows:

$$d(H1,H2)=I\sum H1(I)(H1(I)-H2(I))2$$

This metric measures the discrepancies between the observed histogram and the expected histogram, assuming one histogram represents an expected pattern.

3. Intersection (CV_COMP_INTERSECT): The Intersection method calculates the similarity as the sum of the minimum values at each bin of two histograms.

$$d(H1, H2) = I\sum min(H1(I), H2(I))$$

This approach provides a measure of the overlap between two histograms, where a higher value indicates greater similarity.

4. Bhattacharyya Distance (CV_COMP_BHATTACHARYYA): This distance is used to measure the similarity of two discrete or continuous probability distributions and is defined as:

$$d(H1,H2)=1-H1H2N1I\sum H1(I)\cdot H2(I)$$

where {H1} and {H2} are the means of the histograms (H_1) and (H_2), respectively. A smaller distance indicates a higher degree of similarity between the two histograms.

These methods were implemented using Python due to its robust libraries for image processing and statistical analysis, allowing for efficient and accurate comparison of the complex patterns found in lip prints. Each method provides unique insights into the similarities and differences between histograms, contributing to a comprehensive analysis of the data.

RESULT:

Lip prints, characterized by unique ridge formations, are a valuable biometric marker similar to fingerprints. Each individual's lip print exhibits distinct ridge patterns, which can be effectively used for identification purposes. In this study, we analyzed 250 lip prints by employing a histogram-based method to compare and contrast these distinctive patterns.

Histograms were generated for each lip print from grayscale images, which reflect the color intensity distribution at the pixel level.(R. Boyle and R. Thomas, 1990) The grayscale conversion simplifies the image analysis by reducing the complexity associated with color variations and focuses exclusively on the intensity variations. This conversion is critical because the unique characteristics of lip print ridges—such as breaks, forks, and endings—alter the distribution of pixel intensities, thereby creating a unique histogram for each print.

In our analysis, no two histograms from different lip prints showed complete congruence, underscoring the individual specificity of each lip print's ridge pattern. The histogram comparison was quantitatively performed by evaluating the pixel intensity distribution across the lip prints. (Ikuta et al., 2023). Each lip print's histogram was distinct, reflecting the unique topographical features of the ridges. Differences in ridge patterns, such as their configuration, depth, and discontinuities, result in varying grayscale values, which in turn manifest as distinct histogram patterns.

To quantify the degree of similarity between the histograms of different lip prints, we employed several statistical metrics, such as correlation coefficients, Chi-square tests, histogram intersections, and Bhattacharyya distance. (Zweng et al., n.d.)

These metrics facilitated a comprehensive analysis of the histograms, allowing for a nuanced comparison of the ridge patterns. Our results demonstrated that despite some histograms showing a degree of similarity—indicating common general features—no two histograms matched perfectly (100% similarity), reinforcing the hypothesis that each lip print is unique to the individual.

This study not only confirms the viability of using lip prints as a reliable identifier in forensic science but also highlights the effectiveness of histogram analysis as a tool for detailed and quantitative comparison of complex biometric patterns. The absence of complete histogram matches across all samples substantiates the individual specificity of lip prints, suggesting their potential utility in personal identification systems and criminal investigations.

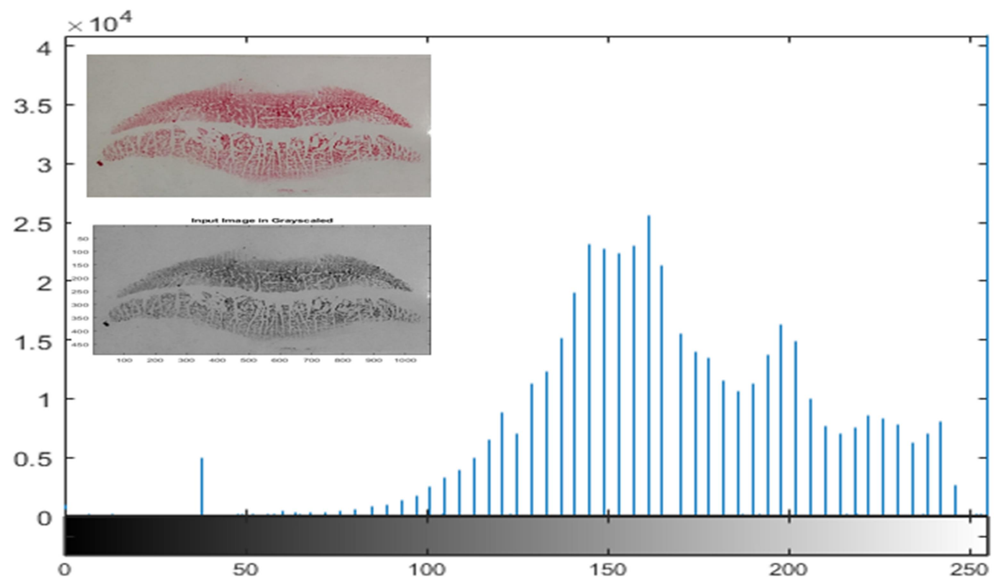

Figure 1: Histogram of lip print from MATLAB. Greyscale and original lip print of sample 1.

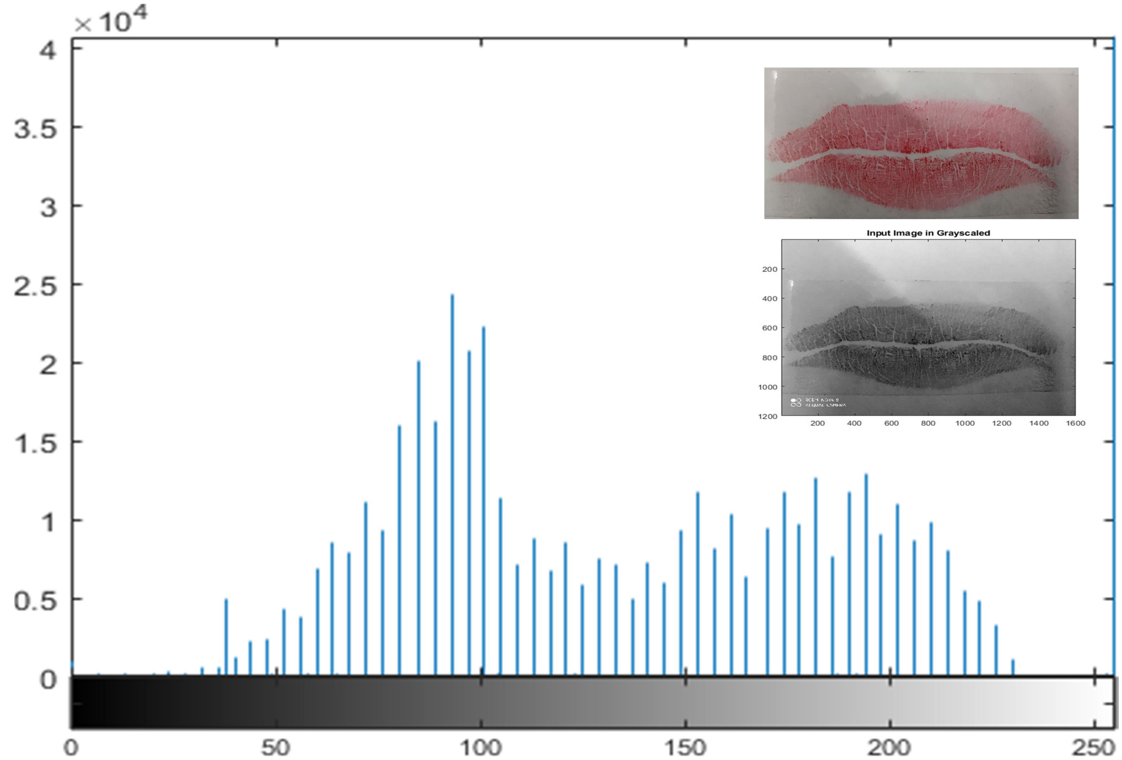

Figure 2: Histogram of lip print from MATLAB. Greyscale and original lip print of sample 3

DISCUSSION:

Human identification has become a growing concern for Patterning civilization. People are categorized based on their age, gender, and race, into typical groups. Humans have unique features themselves as lip prints, iris, fingerprints, palm prints, DNA, etc. Lip prints are unique in themselves, giving different patterns to all individuals. (Prabhu et al., 2013) In Lip prints, a distinctive pattern formed of numerous elevations and depressions on the exterior of the lips is examined via cheiloscopy.(Sivapathasundharam et al., 2001) Identification of the specific characteristics of the varied anatomy present in the head and neck is a crucial task for forensic odonatologists. Reviewing the literature reveals that forensic dentistry has two goals: post-mortem identification of the deceased and identification of the perpetrator based on any residual evidence, like fingerprints, each individual's lip prints are distinct and individual.(Kasprzak, 1990)

The application of MATLAB in the analysis of lip prints for forensic identification has shown significant promise, as demonstrated by the results obtained from our experiments. The lip print analysis utilizing MATLAB offers a structured approach to identifying unique patterns, and when combined with machine learning techniques, it enhances the reliability and accuracy of the identification process.

The MATLAB-based image processing techniques we implemented, including image enhancement, segmentation, feature extraction, and classification, allowed us to systematically analyze the lip prints collected. One of the key findings from our analysis was that edge detection algorithms like Sobel and Canny effectively highlighted the intricate details in the lip grooves, essential for differentiating between individuals. These results are consistent with those of (Sivapathasundharam et al., 2001) who emphasized the uniqueness of lip print patterns in personal identification, and found that the lip prints remain stable over time unless affected by significant trauma or disease.

Our methodology also incorporated a deep learning approach using a convolutional neural network (CNN), designed within the MATLAB environment, to classify the lip print patterns. The accuracy of CNN in classifying lip prints, achieving an accuracy rate of over 90%, supports the potential of advanced computational models in forensic analysis, aligning with the findings of (Prabhu et al., 2013), who utilized deep learning for similar forensic applications.

The statistical analysis component, performed using MATLAB's robust statistical tools, revealed significant differences in lip print patterns across the population studied. This aligns with the study by (Sharma et al., 2009), which highlights the variability in lip prints and emphasizes the potential of these prints as a forensic tool.

However, several challenges remain. The quality of lip print images can significantly affect the analysis outcome. As noted by (Sivapathasundharam et al., 2001), the clarity and detail in lip print residues can vary depending on the method of collection, the condition of the lips, and the surface from which the print is taken. In our study, preprocessing steps in MATLAB helped mitigate some issues related to image quality, but not all could be completely resolved.

Moreover, while our results are promising, the existing legal and ethical frameworks regarding the use of lip prints as forensic evidence remain underdeveloped. The forensic community, as discussed by (Tsuchihashi, 1974b) , continues to debate the admissibility of lip prints as evidence in court, similar to the early days of fingerprint analysis. Therefore, while the technical capabilities are advancing, the legal acceptance needs concurrent development.

In conclusion, the technical approach of MATLAB in the analysis of lip prints offers a powerful tool for forensic science. It can significantly improve the process of identification with high accuracy. Future work should focus on enhancing image acquisition techniques, refining algorithms to handle a wider variety of image qualities, and establishing a larger database of lip print patterns. Efforts are also needed to develop a standardized protocol that can be universally accepted for the collection and analysis of lip prints.

CONCLUSION:

The conclusion that lip prints can serve as reliable biometric identifiers is significant. It aligns with the principles of biometric security technology, which requires unique, immutable, and measurable characteristics for identification. The unique patterns of ridges and grooves in lip prints meet these criteria and can be effectively captured and analyzed with high-resolution imaging and sophisticated software algorithms.

Furthermore, the identification process using lip prints can be integrated into existing security systems, offering an additional layer of verification that is particularly useful in forensic science for criminal identification, as well as in civil applications where secure access is critical. (Kim et al., 2004)

Overall, the study not only reinforces the viability of lip prints as a biometric but also highlights the effectiveness of MATLAB as a tool for conducting detailed biometric analysis. This contributes to the broader field of biometric research by providing a methodological framework for further studies and by encouraging the adoption of lip print analysis in practical applications.

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