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# Intelligent System for Face Recognition on Medically Altered Surgical Images using Machine Learning Algorithms

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**Abstract:** Over the last two decades, there has been a significant increase in the number of plastic surgery procedures performed on the face, ranging from minimally invasive treatments to more extensive surgeries. This trend, which carries social and cultural significance, is expected to continue growing as the cost of these procedures decreases and the desire for physical enhancement becomes more widespread. Consequently, the field of face recognition research faces a new challenge: developing methods that can accurately identify individuals even if their appearance has been altered through facial surgery. Despite previous efforts to overcome challenges such as variations in pose, expression, illumination, aging, and disguise, the rise in plastic surgery necessitates further advancements in this area. While plastic surgery is viewed as a challenging topic of study, there has been little theoretical or experimental research conducted on the subject. The objective of this article is to examine the impact of plastic surgery on facial recognition algorithms. In this paper, the performance of face reconstruction is performed Extended Uniform Circular Local Binary Pattern (EUCLBP), Harmony Search Algorithm and KNN classifier. An open dataset of 1800 before and after images from 900 human faces undergoing plastic surgery was used to test all algorithms. Each individual had two front-facing images taken with appropriate lighting and neutral expressions - one before surgery and one after. The results consistently demonstrated better performance and higher accuracy in identification compared to the current algorithm.

***Keywords***: *-Face Reconstruction, plastic surgery, granular computing, Extended Uniform Circular Local Binary Pattern,* Harmony Search Algorithm *and KNN.*

## 1. Introduction

The banking industry, among others, has transitioned its security measures from relying on passwords to utilizing image processing techniques. The human-machine interface needs the human face recognition system for operation. For security and image processing applications face detection is the major block that does the main role. The primary area of research in biometric systems involves identifying and authenticating faces captured by camera images. Meanwhile, plastic surgery differs from aging in that it is a one-time procedure that can be reversed if needed. Face recognition algorithms are unable to duplicate non-uniform face transmutations because the changes caused by cosmetic surgery treatments are unanticipated [1]. Disguise, on the other hand, is the act of concealing one's true identity via the use of cosmetics and other accessories. Cosmetic surgery encompasses plastic surgery, which involves altering the outward physical features of the face, including reconstructing facial structures, removing birthmarks, moles, and scars, correcting abnormalities caused by diseases, and making changes to the facial shape, among other procedures. Certain people can abuse both plastic surgery and disguise to hide their identity and avoid detection. Changes brought on through disguise are transitory and reversible. In criminal investigations, the process is difficult since the face to be detected and recognized is from a camera that records a video from which the face has to be detected using frame analysis. If an image is taken in poor lighting or harsh weather conditions, the process can become complicated. This leads to the development of more intriguing methods for detecting faces in low-quality or difficult-to-see images [2]. To overcome the problems this research is focused on new methodologies which can detect and recognize faces. The key element in a facial expression system's success is the ability to identify the essential characteristics of a given image or sequence of images of a face. These facial features, once extracted, serve as an effective representation that seeks to increase the differences between categories and minimize variations within categories of expressions. The main scopes of the studies are as follows:

- To separate features from input images for effective reconstruction of facial images using a unified algorithm.
- The goal is to create an algorithm for selecting features that would reduce the size of the feature vector ¬ thereby saving computation time while maintaining a high recognition rate.

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- The obstacles for face construction are mitigated algorithm that compares both pre-operative input image and post-operative input image for change detection based on pixel mapping.
- To develop effective classification techniques using machine learning to make decisions and anticipate the degree of variation that may arise during the classification process.
- Experiment evaluation states the proposed search algorithm gives much better performance.

***Organization of the paper:*** we have already seen an overview of face reconstruction over surgery images in Part 1, in Part 2, the literature review is depicted, the methodology used is described in Part 3, and the performance study has been provided in Part 4, and finally conclusion is covered in Part 5.

## 2. Literature Review

In the last few years, there has been a significant research focus on developing intelligent algorithms for facial recognition. For comparing pre-and post-surgical images of the same person, Vu et al. [2022] [3] employed a sparse representation approach. Although both local and global surgical operations can change the overall look of the face, the post-surgical face usually resembles the original face in parts. Unfortunately, existing recognition algorithms make it challenging to simulate these appearance differences. They developed a part-wise architecture with a sparse representation approach based on these findings to improve face matching across cosmetic surgery variances. For distinguishing local plastic surgery face images, K.R.Singh et al. [2018] [4] proposed a near-sets strategy, which entailed obtaining some feature values geometrically and approximating them with near-sets. A feature database will be established following the extraction of the features. A strategy for generating similar appearances across items in a disjoint set may be established using feature values near set theory. It provides a systematic framework for comparing and categorizing goods based on their appearance.

Anwarul et al. [2020] [5] Provide a detailed summary outlining the essential strategies currently employed to tackle challenges associated with face recognition. The summary should include a breakdown of the accuracy levels associated with each strategy, as well as a discussion of the factors that negatively impact their effectiveness. Singh et al. [2020] [6] The article showcases the different methods used to evaluate the robustness of a facial recognition algorithm, and how these can greatly affect its intended purpose. GANs are employed to explore several types of assaults, such as physical presentation, disguises/makeup, digital adversarial, and morphing/tampering attacks. Moreano et al. [2020] [7] studied is to create a proficient 3D facial recognition system by utilizing Matlab 2015a functions to project face models from the BU-3DFE database onto three planes. The resultant output will be regarded as 2D pictures for recognition purposes. Lin et al. [2020] [8] methods involves utilizing a feature extraction technique to convert thermal images into features. These features are then utilized to construct a facial prediction model employing a combination of deep learning, random forest, and ensemble learning techniques. To generate the feature image, the suggested technique divides the facial image (both RGB and thermal images) into 12 or 48 blocks, depending on the approach used, and creates a feature matrix. Rathgeb et al. [2020] [9] Introducing the newly launched plastic surgery database by Hochschule Darmstadt (HAD) that features pre and post-surgical facial images. The database is in line with the quality standards for electronic travel documents set by the International Civil Aviation Organization (ICAO) and incorporates facial photographs. It meets the ICAO's quality criteria for electronic travel documentation and comprises of facial photographs depicting the five most commonly conducted facial plastic surgeries.

## 3. Methodology

Figure 1 illustrates the stages of the algorithm, while the subsequent sections provide a detailed explanation of each step. The initial stage of face recognition system involves obtaining images from a camera and transferring them to a computational medium via a frame grabber. These images, in the form of digital data, are then fed into the software's face detection algorithm to extract all the faces present in the image. The input component is a necessary requirement for a face recognition system, as it involves the process of image acquisition. In this step, live images are obtained and transformed into digital data to facilitate image-processing computations. The resulting images are then forwarded to a face detection algorithm.

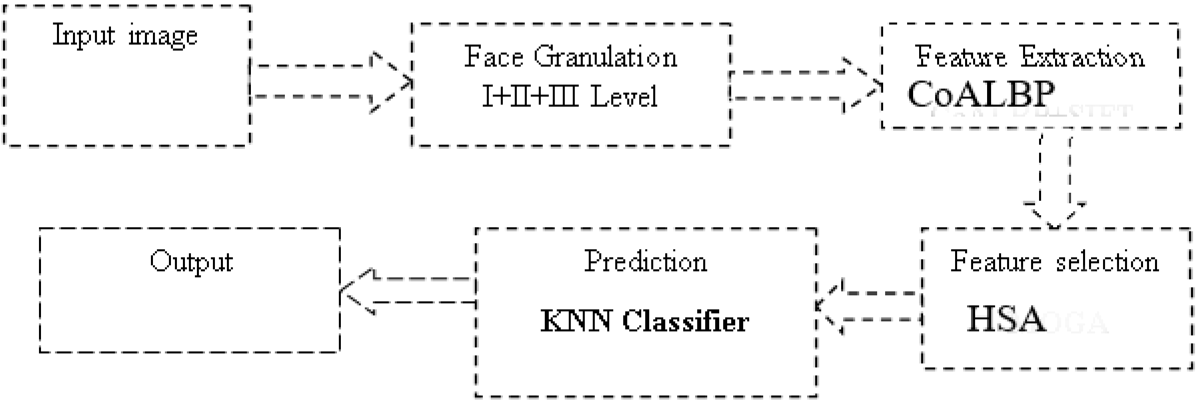


**Fig 1:** Block diagram of proposed work 1

- **Pre-processing**

Pre-processing is a technique that can be employed to enhance the performance of the Face Recognition system and is implemented prior to the face detection process. Image preprocessing contains various kinds of procedures like image sharpness and scaling, remapping of color intensity, and supplementary improvement procedures.

**Fig 3.2:** Input image

Histogram equalization (HE), Histogram Normalization is the most frequently utilized technique for pre-processing. The objective of enhancing contrast in image processing is to modify the image's histogram by utilizing the complete range of discrete levels in order to achieve an improvement in image contrast. The most commonly employed technique for histogram normalization is histogram equalization, which transforms the image's histogram into a uniform distribution that works for all brightness values. This method enhances all areas of the image equally, as depicted in Figure 3, which displays the pre-processed image after applying histogram equalization to the input image shown in Figure 2.

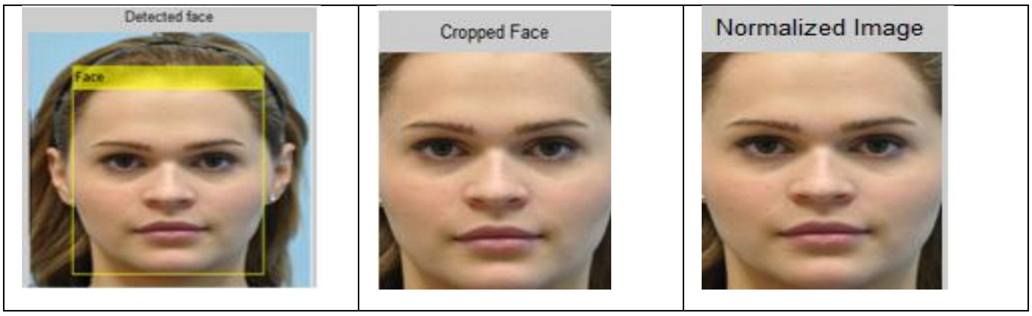


**Fig 3:** Illustrating the detected,cropped and normalized face images

- **Face Image Granulation**

The granular technique extracts facial image characteristics that are not completely separate at different levels of detail. This approach allows for greater flexibility in identifying specific facial features such as the nose, ears, forehead, chin, and cheeks, as well as combinations of these features. The use of granulated information also provides valuable insights into the effects of plastic surgery techniques on various facial features and their surrounding areas. Assuming that there is a frontal facial image identified as size n×m, the images are subjected to low pass filtering using the Gaussian Operator. The Laplacian operator is then utilized to generate a bandpass-filtered version of the images. By breaking down the facial image into distinct segments, both horizontal and vertical granules can be generated. The granules produced using Gaussian and Laplacian operators are depicted in Figures 4 and 5, ranging from G1 to G6. The horizontal granules are identified as G7 to G15, while the vertical granules range from G16 to G24. The interplay between these granules is crucial for addressing changes induced by plastic surgery in areas such as the chin, forehead, ears, and cheeks. The second level of granularity facilitates the analysis of various combinations of local features that contribute to the resilience of multiple regions to simultaneous changes. Granules G17 to G40 represent the third level of granularity from a specific eye coordinate. Utilizing the golden ratio face template, 16 local areas are derived. Figure 6 and 7 display the horizontal and vertical granulation, while Figure 8 illustrates the granulation from G25-40 using the golden facial template.


**Fig 4:** Face Granules created using Gaussian operator (G1, G2, G3)


**Fig 5:** Face Granules created using Laplacian operator (L1, L2, L3)

**Fig 6:** 9 Horizontal Granules generated from step 2 granularity from H1 to H9

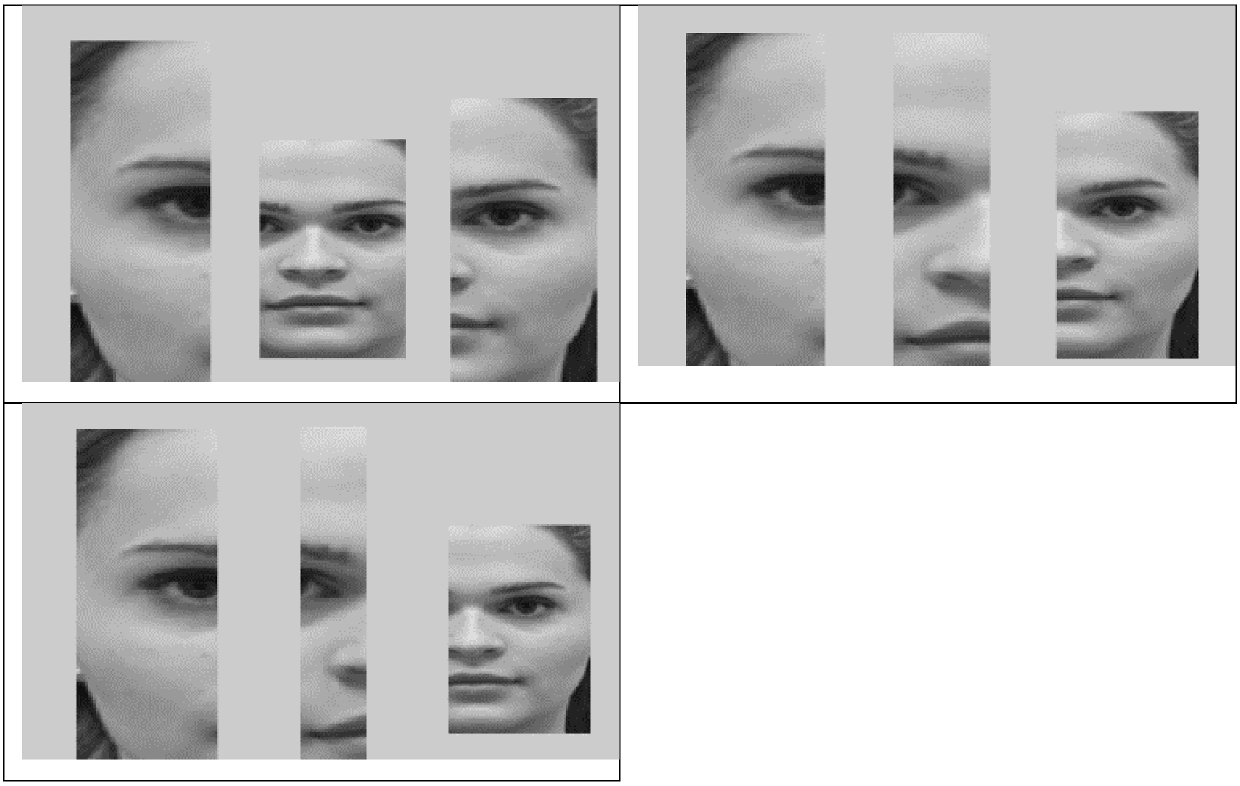

**Fig 7: 9** Vertical Granules generated from step 2 granularity V1 to V9.

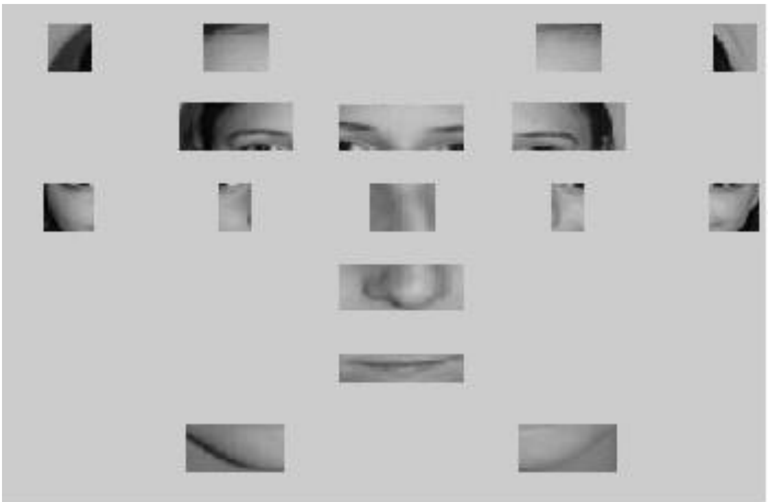

**Fig 8 –** Granules from G25 to G40 using Golden ratio face template.

- **Feature Extraction:** ***Co-occurrence of Adjacent Local Binary Patterns (<u>CoALBP</u>)***

The frequency of occurrence of neighboring Local Binary Patterns (LBPs) is an indicator of how often their pairing appears throughout the whole image. Only a simple visual pattern may be represented by the original LBP. Combining numerous LBPs, on the other hand, may depict a variety of visual patterns obtained from more intricate surfaces. The number of possible LBP combinations in the proposed feature is significantly larger than the number of original LBP combinations. It can be difficult to use rule-based software to calculate the co-occurrence of all combinations when there are various types of Local Binary Patterns (LBPs). To overcome this challenge, an auto-correlation matrix can be employed to identify the co-occurrence of LBPs rather than using a heuristic technique. To save time and resources, a modified LBP configuration is used that examines two sparser configurations instead of the original eight neighboring pixels around a given center pixel [11].

We assume the $N_p \times N_p$ auto-correlation matrix supplied by the following equation to properly identify the co-occurrence of LBPs:

$$\mathrm{H(a)} = \sum_{r \epsilon I} f(r)\, f(r+a)^T \qquad (1)$$

The vector 'a' represents the displacement from the reference LBP to the adjacent LBP.

To determine how frequently adjacent Local Binary Patterns (LBPs) occur in an image, their co-occurrence is measured. This co-occurrence index is a measure of how often these LBPs appear in combination across the entire image. When dealing with complex surface patterns, the number of possible LBP combinations in a proposed feature is significantly larger than in the original LBPs. Hence, it becomes challenging to use rule-based programs to calculate the co-occurrence of all LBP combinations, as there are many types of LBPs. To overcome this challenge, an auto-correlation matrix is introduced as a more effective approach to calculating LBP co-occurrence than using a heuristic program. Initially, the Local Binary Pattern (LBP) method utilized eight neighboring pixels surrounding a central pixel. However, we have altered the LBP setup to include two more sparse configurations. This modification helps to minimize the computational expenses involved. To accurately determine the co-occurrence of LBPs, we convert each LBP to a vector f(∈ R^(N_p ) ), which is defined in the subsequent manner:

$$f_i(\gamma) = \delta_{i,l(b(\gamma))} \qquad (2)$$

where, $N_p$ is the number of all the possible LBPs, $N_p$ = $2^{N_n}$ Nn is the number of neighbor pixels, $\delta_{i,j}$ is Kronecher's delta, and $l(b(\gamma))$ is the label of $b(\gamma)$.

In order to accurately compute the co-occurrence of LBPs, we take into account the auto-correlation matrix with dimensions of N_p×N_p, as expressed by the following equation.

$$H(a) = \sum_{r \epsilon I} f(r) f(r+a)^T \qquad (3)$$

where a is the displacement vector from the reference LBP to its neighbor LBP. The element $H_{i,j}(a)$of Eq.(3) indicates the number of pairs of adjacent LBP i LBP j. Despite having a high dimensionality of (4 $N_p^2$2), the computational cost of the proposed feature is low because of the sparse nature of LBP. By using equation (3) to define matrix H(a), the original LBP histogram can be obtained by summing up the column vectors. As a result, the proposed feature includes both the original LBPs and cooccurrence information, making it a seamless extension of the original LBP.

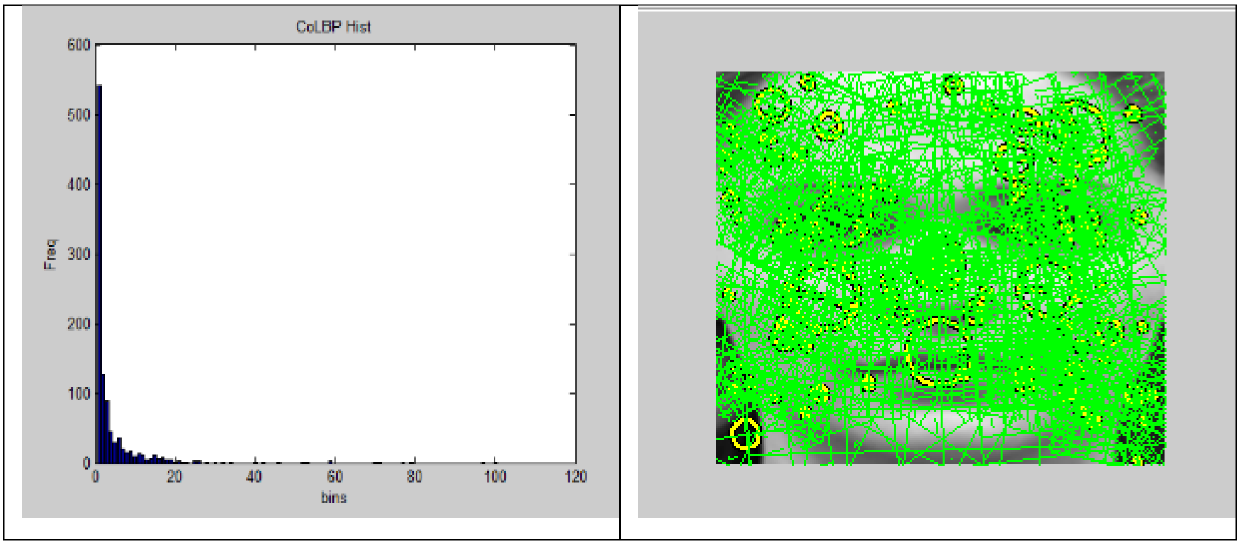


**Fig 9.** Feature extracted output using CoALBP and SIFT

### *3.2.2. Feature Selection: Harmony Search Algorithm*

The Harmony Search (HS) approach appears to be a musical improvisation-influenced meta-heuristic tool kit. It has been used to solve a variety of optimization issues, and there are multiple application-oriented research articles available [12]. Therefore, rather than focusing on applications, this review article attempts to focus on the historical development of algorithm design. A predetermined number of musicians strive to tune the pitch of their instruments to create a nice harmony during the music improvisation process (best state). A particular relationship between various frequencies defines harmony in nature. Aesthetic judgment depends upon the quality of the improvised harmony. The musicians put in a lot of effort, practicing in order to develop their artistic judgment and find the best harmony.

The improvisational and optimizing procedures of musicians have certain parallels. The ultimate goal of an optimal control problem is to tune a set number of choice variables to obtain the global optimum of the objective function in question. The decision variables do form a candidate solution in an optimization problem. The choice variables' numbers are then entered into the objective function, and the solution vector's quality is determined. During each iteration, the solution vector is updated until the global optimum is found.

When musical and optimization processes are compared, the following commonalities emerge:

- Aesthetic evaluation is used to judge the quality of harmony in a musical process. The resulting value of an optimization method depends upon the quality of a solution vector.
- The ultimate objective of musical composition is to achieve the best (amazing) harmony possible. The primary goal of an optimization process is to discover the most excellent solution available globally.
- The pitch of artists' instruments is changed during the musical procedure. The parameters of the decision variables are modified by an optimization method.

Any attempt to play a harmony is referred to as practice in the musical procedure. Iteration is the term used in optimization to describe each effort to update a candidate solution. These steps are similar in the case of feature extraction. That is:

1. Select a feature value from the memory.
2. Select an adjacent feature of one value from the memory.
3. Pick a number at random from a range of possibilities.

All participants in the Harmony Memory are used in the analysis. If a superior solution is discovered than the bad response in Harmony Memory, the bad response should be replaced by the excellent solution; else, the bad answer should be removed.

Figure 10 shows the fitness evaluation response and Figure 11 depicts the feature selection index with the use of the HSA approach.


**Fig 10:** Fitness Evaluation response using HSA Algorithm

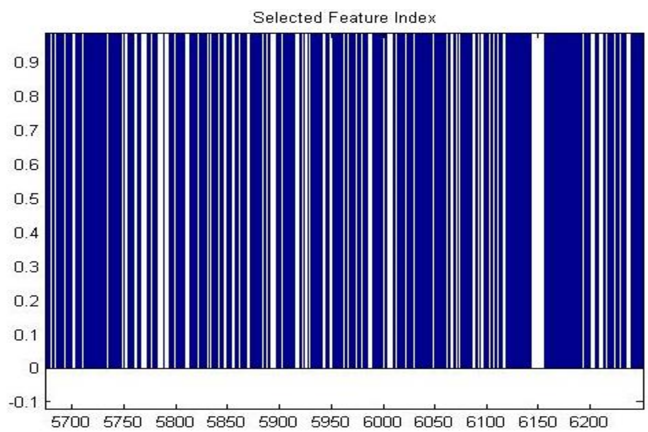


**Fig 11.** Feature selection response using HSA Algorithm

The search operation is carried out until convergence is achieved, and then it is terminated when the accuracy of the identification is adequate

- ***Feature Matching: KNN***

The Multi-feature extraction comprises many approaches which give KNN classifier to extract and selected features then the next step is to classify the image. Many researchers employ the k-nearest neighbor algorithm as a classifier in their face recognition systems due to its simplicity. This approach involves assigning a new object to a class based on the majority vote of its k closest neighbors, where k is typically a small positive integer. When k equals 1, the object is assigned to the class of its nearest neighbor. The classification process involves calculating the Euclidean distance to classify the new object [13].

An instance-based classifier is used to generalize the local sensitivity with a high degree of classification. This approach, commonly known as the K-nearest neighbor algorithm, is a simple technique that relies on an instance space and labeling to determine similarities between known and new cases. By locating all available cases and measuring their similarity, new cases can be classified locally and accurately. Due to the high degree of the training data on noise which has highly susceptible and the lack of robustness that characterize the resulting classifiers. This KNN classifier referred to nearest neighbor that can be regarded in a special case that has more in general to outcome the class labeling. The KNN algorithm runs as the measurement that has no underlying assumption because the static structure of data is about to have nonparametric classifier in K-nearest neighbor (KNN). The distance between the two feature vectors in the test query is determined using a distance function d(x, y), where x and y are the feature vectors being represented.

$$X = \{x_1, x_2, x_3 \ldots.\}$$

$$Y = \{y_1, y_2, y_3 \ldots.\}$$

Euclidean distance

$$d_A(x, y) = \sum_{i=1}^{N} \sqrt{x_i^2 - y_i^2} \quad (4)$$

Normalization of feature vectors is necessary prior to running the classification algorithm in KNN, due to the influence of these features on the overall performance of the algorithm.

1 The class store and training set is used by the KNN algorithm that consists of some features in the database.
2 All the training and test features are calculated between the distances.
3 It determines the K nearest neighbor that is sorted by the distance.
4 In the KNN classification algorithm, the classification of performance is determined by comparing its input features with those of the training features, using a set distance, and considering the labeled classes that are shared by both.

The test's class assignment is determined by K nearest neighbors, which either average the class numbers or obtain a majority vote of the K nearest reference points. This method employs a simple minority category that is assigned to the test, and thus the performance is uncertain.

If the descriptors estimated from the face granules are 'a' and 'b,' feature matching may be done using the formula.

$$X^2(a, b) = \sum_{i.j} wj \frac{(a_{i,j} - b_{i,j})^2}{a_{i,j} + b_{i,j}} \quad (5)$$

Finally, the test image is compared with each and every image in the training data set and classify the images using the KNN classifier.


**Fig 12:** Matched output

The approach is built using MATLAB (Matrix Laboratory) and runs on Windows 10 with 2GB RAM and an Intel core CPU. There are 40 granules from the three levels of granularity. Even the tiniest details must be retrieved from each of the grains. It is evident from the 40 granules that some have fiducial information and others do not. As a result, we must select the right feature extractor. Table 1 illustrates the accuracy of various techniques.

**Table 1.** Overall analysis of various models

| Models | Accuracy | Sensitivity | Specificity | Precision | Recall | F1-score | G-mean | Images |
|---|---|---|---|---|---|---|---|---|
| proposed | 0.961 | 1 | 0.92 | 0.36 | 1 | 0.51 | 0.95 | Image 1 |
| | 0.923 | 1 | 0.925 | 0.367 | 1 | 0.513 | 0.956 | Image 2 |
| | 0.9236 | 1 | 0.93 | 0.37 | 1 | 0.516 | 0.96 | Image 3 |
| | 0.934 | 1 | 0.935 | 0.376 | 1 | 0.518 | 0.962 | Image 4 |
| | 0.938 | 1 | 0.938 | 0.38 | 1 | 0.52 | 0.967 | Image 5 |
| | | | | | | | | |
| [14] | 0.85 | 1 | 0.85 | 0.24 | 1 | 0.43 | 0.86 | Image 1 |
| | | | | | | | | |
| [15] | 0.82 | 1 | 0.82 | 0.22 | 1 | 0.30 | 0.83 | Image 1 |

Table 3 depicts the overall analysis of classification approach with the use of a granular over various other current models. Here the proposed model achieves the best result.

## 4. Conclusions

The growing popularity of plastic surgery and other cosmetic procedures is posing a significant obstacle for facial recognition technology in uncontrolled settings. This is particularly problematic in forensic contexts, where criminals may intentionally modify their facial features to evade detection. With the increasing prevalence of plastic surgeries, even among the younger population, facial recognition could face similar challenges in other applications as well. The proposed algorithm is implemented using MATLAB software and the results are verified. The method being proposed employs CoALBP, HSA, and KNN to extract image features and address local illumination. By utilizing this approach, multiple features can be extracted, selected, and classified. In future the comparison and detail analysis will be made. Proposal is to be made to introduce the feature selection method for optimization of neural network parameters so the convergence will narrow down. The integration of machine learning methodologies and neural networks is expected to improve the system's performance. The outcomes presented in the experimental section indicate that the suggested technique can achieve highly efficient facial recognition, surpassing several other state of-the-art methods

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