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An Innovative Mean Approach for Plastic Surgery Face Recognition

Mahendra P. Randive[1], Umesh W. Hore[2]

[1] Student of M.E., Department of Electronics & Telecommunication Engineering, P. R. Patil College of Engineering, Amravati Maharashtra – India

[2] Assistant Professor, Department of Electronics & Telecommunication Engineering, P. R. Patil College of Engineering, Amravati Maharashtra – India

Abstract: ***Among various biometric person identification systems face recognition is most popular as it doesn't need the object's cooperation. The actual advantages of face based identification over other biometrics are uniqueness and acceptance. Popularity of plastic surgery procedures is further increased by affordability and various advanced techniques. Facial plastic surgery can be reconstructive to correct facial feature anomalies or cosmetic to improve the appearance. Both corrective as well as cosmetic surgeries alter the original facial information to a great extent thereby posing a great challenge for face recognition algorithms. It has been observed that many face recognition algorithms fail to recognize faces after plastic surgery, which thus poses a new challenge to automatic face recognition. There are several effective methods invented in recent past but they are effective only under certain conditions like illumination, pose, occlusion, etc. So here we are suggesting an innovative approach to find out a mean method that will provide the most accurate result even after the subject has undergone a plastic surgery with higher accuracy and better response rate. In this method we will find a mean image, which is obtained by applying several popular methods like PCA, LBP, Periocular biometrics and Gabor Filter method to the test image along with Euclidean distance measurement for comparing pre and post-surgery face images.***

Keywords: Plastic Surgery, Periocular Region, Feature Extraction.

1. Introduction

In recent years, plastic surgery has become popular worldwide. People take facial plastic surgery to correct feature defects or improve attractiveness and confidence. According to the American society's 2014 report there have been 15.6 million cosmetic procedures and 5.7 million reconstructive procedures performed in the year 2014, the 3 percent increase than 2013. Among the cosmetic surgical procedures the top five are Breast augmentation, Nose reshaping, Eyelid surgery, Liposuction and Facelift [1]. 2013 report shows that the percentage of persons going for plastic surgery is highest in the age ranging from 40 to 54 years old.

It also shows that 91% of all the cosmetic surgeries are performed by females [1]. Facial plastic surgery is generally used for correcting feature defects or improving the appearance, for example, removing birth marks, moles, scars and correcting disfiguring defects. The allure for plastic surgery is experienced world-wide and is driven by factors such as the availability of advanced technology, affordable cost and the speed with which these procedures are performed. These surgical procedures prove beneficial for patients suffering from structural or functional impairment of facial features, but these procedures can also be misused by individuals who are trying to conceal their identity with the intent to commit fraud or evade law enforcement.

Figure 1: Illustrating the variations in facial appearance, texture, and structural geometry caused due to plastic surgery (images are taken from internet)

These surgical procedures may allow anti-social elements to freely move around without any fear of being identified by any face recognition system. Plastic surgery, results being long-lasting or even permanent, provide an easy and robust way to evade law and security mechanism [3], [6]. Sometimes, facial plastic surgery may unintentionally cause rejection of genuine users. While face recognition is a well-studied problem in which several approaches have been proposed to address the challenges of illumination, pose, expression, aging and disguise, the growing popularity of plastic surgery introduces new challenges in designing future face recognition systems [8].Since these procedures modify both the shape and texture of facial features to varying degrees, it is difficult to find the correlation between pre and post-surgery facial geometry [6].

1.1 Types of Facial Plastic Surgery

When an individual undergoes plastic surgery, the facial features are reconstructed either globally or locally.

Therefore, in general, plastic surgery can be classified into two distinct categories.

- Disease correcting local plastic surgery (Local surgery): This is a kind of surgery in which an individual undergoes local plastic surgery for correcting defects, anomalies, or improving skin texture[6].
- Plastic surgery for reconstructing complete facial structure (Global surgery): Apart from local surgery, plastic surgery can be performed to completely change the facial structure which is known as full face lift [6].

2. Proposed Methodology

This paper proposes a new simple and innovative approach for the face recognition after plastic surgery. This method makes the use of different features from face and periocular region to match face images before and after plastic surgery. The block diagram of proposed method is shown in Figure 2. To extract the features from both face and periocular biometrics local binary pattern feature extractor is used along with principal component analysis to reduce the dimensions. Then Euclidian distance is used for classification of processed images. The distance metric from each method is calculated and the image with minimum distance metric is selected as the recognized face image. The block diagram has the following steps: Preprocessing, Feature Extraction, Classification.

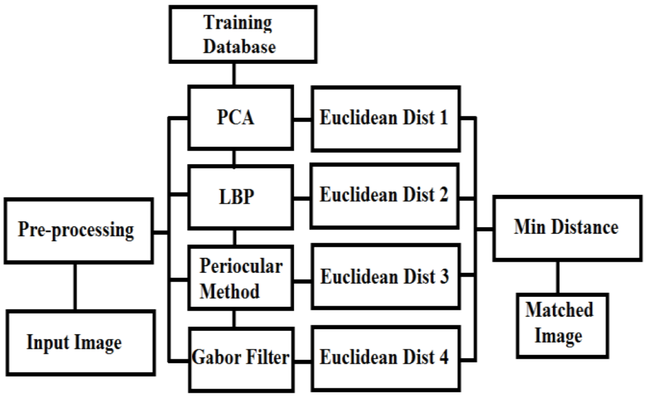


Figure 2: Proposed Block Diagram

2.1 Preprocessing

The pre-processing of the raw images is very important step in face recognition system. For proper analysis, comparison or manipulation of various objects in the image we need to do the preprocessing in order to level the various field such as cardiac cross sections and spines needed to occupy the same area in the coordinate plane. Data pre-processing describes any type of processing performed on raw data to prepare it for another processing procedure. Data pre-processing changes the data into a format that will be more easily and effectively processed for the purpose of the user. The feature and information of face image should not be altered by local changes due to noise and illumination error [1]. Hence to satisfy the environmental conditions, preprocessing of the raw data is highly important [4]. The change in resolution of various image capturing devices results in different resolution of the captured images. Hence to increase the accuracy and to decrease the computational efforts all the images should be made uniform in size. Alignment of face image is also necessary to have a better result.

2.2 Feature Extraction

Feature extraction is done after the preprocessing phase. Features should contain information required to distinguish between classes, be insensitive to irrelevant variability in the input, and also be limited in number, to permit, efficient computation of discriminant functions and to limit the amount of training data required. Feature extraction is an important step in the construction of any pattern classification and aims at the extraction of the relevant information that characterizes each class. In this process relevant features are extracted from objects to form feature vectors. These feature vectors are then used by classifiers to recognize the input unit with target output unit. It becomes easier for the classifier to classify between different classes by looking at these features as it allows fairly easy to distinguish. Feature extraction is the process to retrieve the most important data from the raw data. Feature extraction is finding the set of parameter that define the shape of a character precisely and uniquely. The major goal of feature extraction is to extract a set of features, which maximizes the recognition rate with the least amount of elements and to generate similar feature set for variety of instance of the same symbol. In this proposed method we will use the LBP and PCA for feature extraction.

2.2.1 Local Binary Pattern

The LBP operator [13] is one of the best performing texture descriptors and it has been widely used in various applications. It has proven to be highly discriminative and its key advantages, namely, its invariance to monotonic gray-level changes and computational efficiency, make it suitable for demanding image analysis tasks [13]. As a non-parametric method, LBP summarizes local structures of images efficiently by comparing each pixel with its neighboring pixels. The most important properties of LBP are its tolerance regarding monotonic illumination changes and its computational simplicity [9]. The original LBP operator labels the pixels of an image with decimal numbers, called Local Binary Patterns or LBP codes, which encode the local structure around each pixel. It proceeds thus, as illustrated in Fig.3 Each pixel is compared with its eight neighbors in a 3x3 neighborhood by subtracting the center pixel value; The resulting strictly negative values are encoded with 0 and the others with 1.A binary number is obtained by concatenating all these binary codes in a clockwise direction starting from the top-left one and its corresponding decimal value is used for labeling. The derived binary numbers are referred to as Local Binary Patterns or LBP codes.

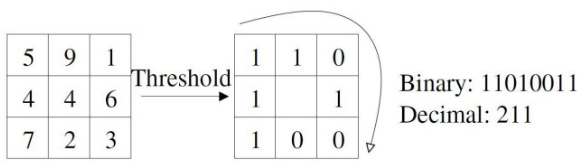


Figure 3: An example of the basic LBP operator

One limitation of the basic LBP operator is that its small 3x3 neighborhood cannot capture dominant features with large scale structures. To deal with the texture at different scales, the operator was later generalized to use neighborhoods of different sizes [9]. A local neighborhood is defined as a set of sampling points evenly spaced on a circle which is centered at the pixel to be labeled, and the sampling points that do not fall within the pixels are interpolated using bilinear interpolation, thus allowing for any radius and any number of sampling points in the neighborhood. Fig. 4 shows some examples of the extended LBP operator, where the notation *(P, R)* denotes a neighborhood of *P* sampling points on a circle of radius of *R*.

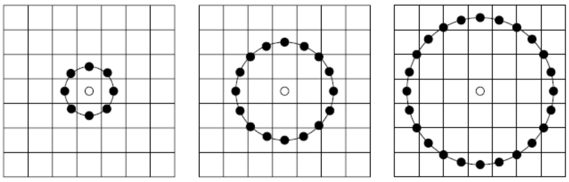


Figure 4: Examples of the extended LBP operator [20]: the circular (8, 1), (16, 2) and (24, 3) neighborhoods.

Formally, given a pixel at (x_c, y_c), the resulting LBP can be expressed in decimal form as:

$$LBP_{P,R}(x_c, y_c) = \sum_{P=0}^{P-1} s(i_P - i_c)2^P \quad (1)$$

Where i_c and i_p are respectively gray-level values of the central pixel and *P* surrounding pixels in the circle neighborhood with a radius *R*, and function *S(x)* is defined as:

$$s(x) = \begin{cases} 1 & if \quad x \geq 0 \\ 0 & if \quad x < 0 \end{cases} \quad (2)$$

By the definition above, the basic LBP operator is invariant to monotonic gray-scale transformations preserving pixel intensity order in the local neighborhoods. The histogram of LBP labels calculated over a region can be exploited as a texture descriptor. The facial image is divided into local regions and texture descriptors are extracted from each region independently. The descriptors are then concatenated to form a global description of the face. See Fig.5 for an example of a facial image divided into rectangular regions.

Figure 5: A facial image divided into 7x7, 5x5 and 3x3 Rectangular Region

The basic histogram can be extended into a spatially enhanced histogram which encodes both the appearance and the spatial relations of facial regions. As the m facial regions R0, R1….Rm-1 have been determined, a histogram is computed independently within each of the m regions. The resulting m histograms are combined yielding the spatially enhanced histogram. The spatially enhanced histogram has size m x n where n is the length of a single LBP histogram.

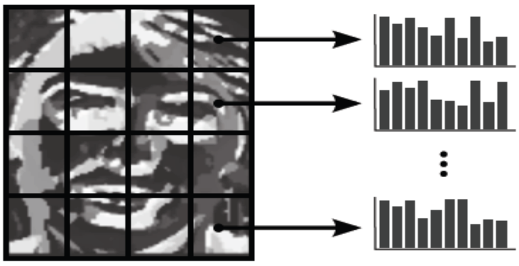


Figure 6: LBP descriptors are built by partitioning the LBP face image into a grid and computing LBP histograms over each grid cell. These histograms may then be concatenated into a vector or treated as individual descriptors.

2.2.2 Principal Component Analysis (PCA)

Principal Component Analysis is a mathematical algorithm that reduces the dimensionality of the data while retaining most of the variation in the data set. It accomplishes this reduction by identifying directions, called principal components, along which the variation in the data is maximal. By using a few components, each sample can be represented by relatively few numbers instead of by values for thousands of variables. Samples can then be plotted, making it possible to visually assess similarities and differences between samples and determine whether samples can be grouped. PCA for face recognition is based on the information theory approach. It extracts the relevant information in a face image and encodes as efficiently as possible. It identifies the subspace of the image space spanned by the training face image data and decor relates the pixel values. The classical representation of a face image is obtained by projecting it to the coordinate system defined by the principal components. The projection of face images into the principal component subspace achieves information compression, decor relation and dimensionality reduction to facilitate decision making. In mathematical terms, the principal components of the distribution of faces or the eigenvectors of the covariance matrix of the set of face images, is sought by treating an image as a vector in a very high dimensional face space [14].We apply PCA on this database and get the unique feature vectors using the following method .Suppose there are P patterns and each pattern has t training images of m x n configuration.

- The database is rearranged in the form of a matrix where each column represents an image.
- With the help of Eigen values and Eigen vectors covariance matrix is computed.
- Feature vector for each image is then computed. This feature vector represents the signature of the image. Signature matrix for whole database is then computed.
- Euclidian distance of the image is computed with all the signatures in the database.
- Image is identified as the one which gives least distance with the signature of the image to recognize.

2.2.3 Periocular Biometrics

Periocular area (i.e. a region surrounding the eye) is considered to be one of the most discriminative regions of a face [5] and is used for identifying an individual. The use of periocular region may be beneficial in situations where the face is partially occluded, or the subjects have facial hair, etc. Also, it has been proposed in some recent approaches that part-based face representation as opposed to the traditional holistic face representation, may lead to improved face recognition performance [7]. The low-level features extracted from the periocular region can be effectively used for identification [2]. There is no database available with periocular region images. Only way to fetch this is using a face image. There are three different ways to perform Periocular biometric such as overlapping, Non-overlapping and Strip [5].

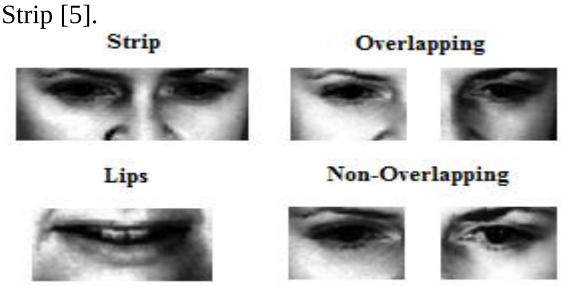


Figure 7: Different types of periocular regions

LBP and PCA are used on this periocular data to extract features and to form reduced dimension templates which will be then used for classification

2.2.4 Gabor Filter

Among various wavelet bases, Gabor functions provide the optimal resolution in both the time (spatial) and frequency domains. Face recognition is one of the most important applications of Gabor wavelets. The face image is convolved with a set of Gabor wavelets and the resulting images are further processed for recognition purpose. The Gabor wavelets are usually called Gabor filters in the scope of applications. It has better response in case of occlusion and illumination changes also miss- alignment [17]. In this method, Gabor wavelet transform is used for facial feature vector construction due to its powerful representation of the behavior of receptive fields in human visual system (HVS) [16] .The method is based on selecting peaks (high energized points) of the Gabor wavelet responses as feature points. The feature points are automatically extracted using the local characteristics of each individual face in order to decrease the effect of occluded features. Since there is no training as in neural network approaches, a single frontal face for each individual is enough as a reference. 2 D Gabor functions are similar to enhancing edge contours, as well as valleys and ridge contours of the image. This corresponds to enhancing eye, mouth, nose edges, which are supposed to be the main important points on a face. Moreover, such an approach also enhances moles, dimples, scars, etc. Hence, by using such enhanced points as feature locations, a feature map for each facial image can be obtained and each face can be represented with its own characteristics without any initial constrains. Having feature maps specialized for each face makes it possible to keep overall face information while enhancing local characteristics. Here we will select peaks (high energized points) of the Gabor wavelet responses as feature points, instead of using predefined graph nodes as in elastic graph matching which reduces the representative capability of Gabor wavelets. Feature vectors are constructed by sampling Gabor wavelet transform coefficients at feature points.

An image can be represented by the Gabor wavelet transform allowing the description of both the spatial frequency structure and spatial relations. Convolving the image with complex Gabor filters with 5 spatial frequency (v =0,…,4) and 8 orientation (μ = 0,…,7) captures the whole frequency spectrum, both amplitude and phase (Figure 8).

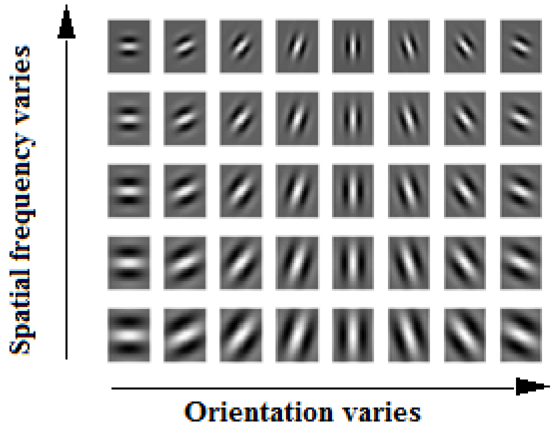
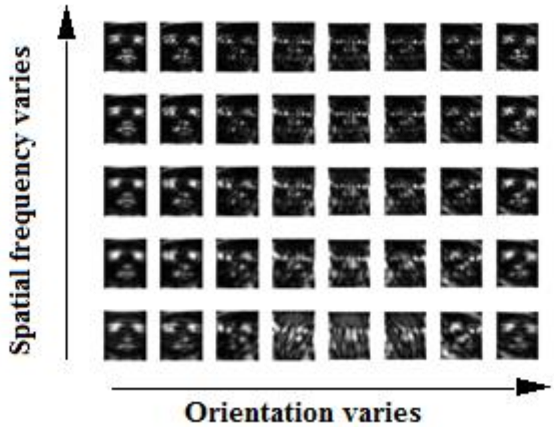


Figure 8: Gabor filters correspond to 5 spatial frequency and 8 orientation.

In Figure 9, an input face image and the amplitude of the Gabor filter responses are shown.

(a)



(b)

Figure 9: Example of a facial image response to above Gabor filters, a) original face image and b) filter responses.

Feature extraction algorithm for the proposed method has two main steps (Figure 10): (1) Feature point localization, (2) Feature vector computation.

In this step, feature vectors are extracted from points with high information content on the face image. In most feature-based methods, facial features are assumed to be the eyes, nose and mouth. However, we do not fix the locations and also the number of feature points in this work. The number of feature vectors and their locations can vary in order to better represent diverse facial characteristics of different faces, such as dimples, moles, etc., which are also the features that people might use for recognizing faces. From the responses of the face image to Gabor filters, peaks are found by searching the locations in a window *W0* of size *W x W* by the following procedure:

A feature point is located at *(x0, y0)*, if

$$R_j(x_0,y_0)=\max_{(x,y)\in W_0}(R_j(x,y)) \qquad (3)$$

$$R_j(x_0,y_0) > \frac{1}{N_1N_2}\sum_{x=1}^{N_1}\sum_{y=1}^{N_2} R_j(x,y) \qquad (4)$$

j=1,…, 40

Where *Rj* is the response of the face image to the *jth* Gabor filter (3). *N1 N2* is the size of face image, the center of the window, *W0* is at *(x0, y0)*. Window size *W* is one of the important parameters of proposed algorithm, and it must be chosen small enough to capture the important features and large enough to avoid redundancy. Equation (4) is applied in order not to get stuck on a local maximum, instead of finding the peaks of the responses. In our experiments a *9x9* window is used to search feature points on Gabor filter responses. A feature map is constructed for the face by applying above process to each of 40 Gabor filters.

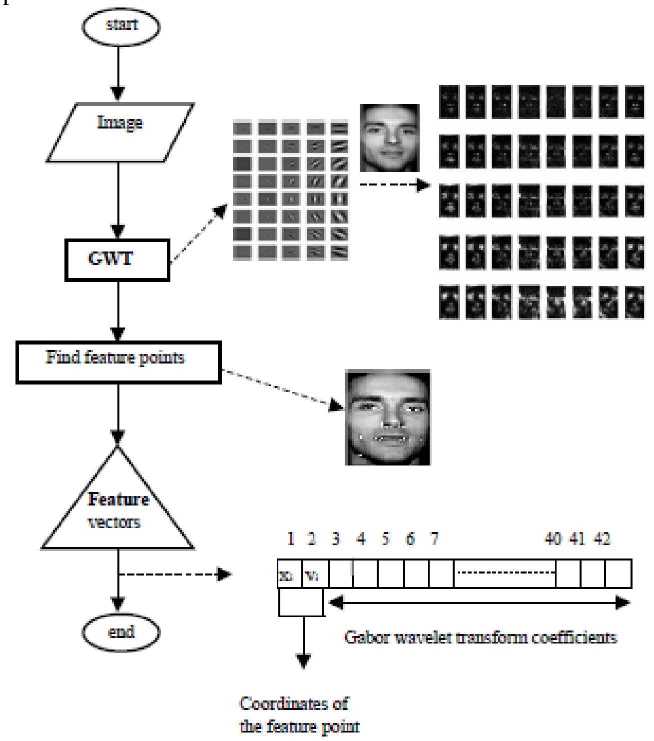


Figure 10: Flowchart of the feature extraction stage of the facial images.

Feature vectors, as the samples of Gabor wavelet transform at feature points, allow representing both the spatial frequency structure and spatial relations of the local image region around the corresponding feature point. After feature vectors are constructed from the test image, they are compared to the feature vectors of each reference image in the database.

2.3 Classification

Euclidean distance can be used for the classification to identify the image in the training set to which the test image belong. Classification will be performed by comparing the feature vectors (weight matrix) of the images in the training set with the feature vectors calculated by four used methods on the test image, using Euclidian distance, ε_i [5].

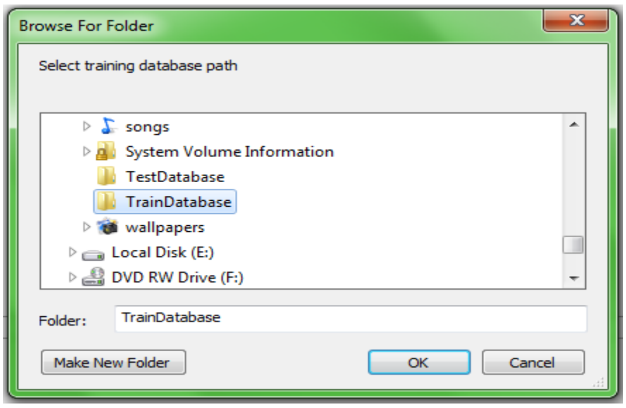
$\varepsilon_i^2 = ||\Omega_T - \Omega i||^2$ (5) Where Ωi is a vector describing the ith face image in the training set. Thus minimum ε_i is calculated for each method used viz. LBP,PCA ,Periocular and Gabor filter and finally among the four face images with minimum ε_i image having minimum ε_i among them will be selected as the recognized image.

3. Result and Discussion

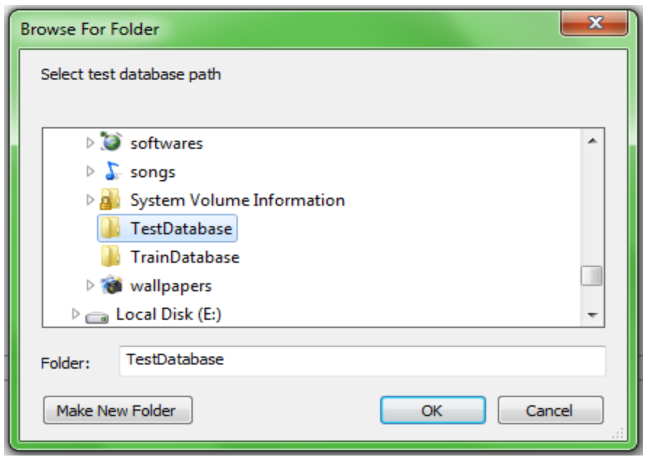
Here depending on the performance of four different algorithms we are calculating final least distance metric and accordingly selecting the image from the face database. The recognition rate will be different for different types of plastic surgeries and the mean recognition rate is approximately 80 percent.

Steps to perform recognition are as follows:

1) Select the path of training database which contains the pre-surgery face images.



2) Select the path of testing database which contains the post-surgery face image.



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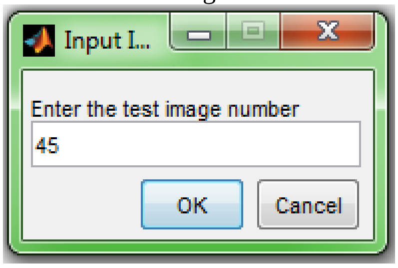
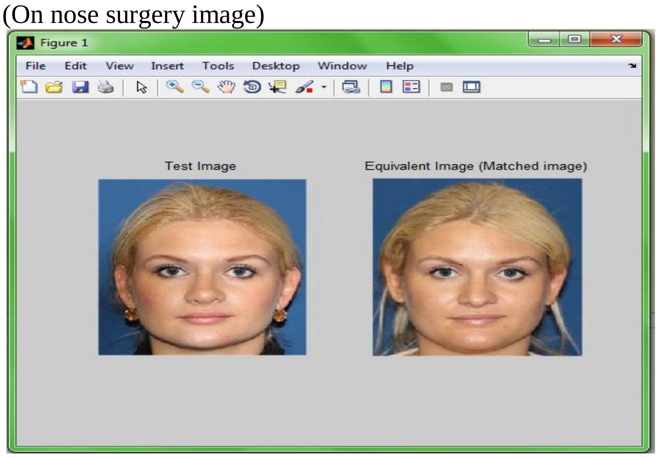
3) Enter the number of test image.



4) Then feature is extracted from test image and all train images using PCA and Euclidian distance E1 is calculated between that images. Again the feature is extracted from test and train image using LBP and minimum distance E2 is calculated between that images. Now, the periocular region is cropped from the test and train image and then extraction of feature is done with the help of LBP and minimum distance E3 is calculated between that images. Same procedure is carried out for Gabor filter method. Finally Test image is classified as belonging to train image of minimum of E1, E2, E3 and E4.

5) Result of proposed method on Plastic-surgery face image. (On nose surgery image)



4. Conclusion

The trend of facial plastic surgery has been increased drastically and many are using it for hiding their identity. Currently there are very few approaches available to detect faces after plastic surgery with high identification rate. To extract the features we will use holistic as well as part wise approach to increase the performance. Different methods give better response in different surrounding conditions. So, here in this paper we have given a new approach based on PCA, LBP, Periocular biometrics and Gabor filter which will not only be simpler than others but also more efficient and unaffected by environmental changes like occlusion, illumination , pose etc. when applied.

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Author Profile

Mr. Mahendra Panjabrao Randive received B. Tech. degree in Electronics and Tele-Communication Engineering from Government College of Engineering Amravati in 2011 and currently he is pursuing M.E. (ExTC) in P .R. Patil College of Engineering, Amravati, Maharashtra, India. His area of interest is Image Processing and Signals & Systems and has published one international paper till now.

Prof. Umesh W. Hore received M. E. Degree (Digital Electronics) in 2011 and is now Assistant Professor in P. R. Patil College of Engineering, Amravati, Maharashtra, India. His area of interest is Image Processing and has published 6 international and 4 national research papers till now.