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Facial Mole Detection: An Approach towards Face Identification

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Abstract

Face is the most significant biometric as it reveals a person's identity more accurately. Soft biometric traits like facial marks have played a crucial role in identifying a human face. The paper presents an automatic prominent mole detection and validation technique which can reduce the adverse effect of illumination in face recognition. Normalized cross-correlation with LoG filter is used to detect the facial mole candidates. A contributory threshold based step is introduced in this paper to improve the accuracy of the mole detector. The mole detection rate is 91.67 % using our own developed "DeitY-TU" face database and 90.58% using FEI face database.

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Keywords: DeitY-TU Face Database; Normalized Cross Correlation; Laplacian of Gaussian; Segmentation

1. Introduction

In the era of advanced technology, identifying and authenticating an individual by means of some unique biometric traits has been intensively adopted in many security applications due to several advantages of the biometric features: universality, robustness and fast authentication[1]. Face recognition is most commonly used in almost every security system due to its ability to identify a person more accurately. This face recognition technology

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can be used in intrusion detection and security systems, to identify known offenders or register suspects from a preloaded criminal database in order to take some proactive defensive measures. Moreover, in certain applications like surveillance, where an occluded face image or face image in off-frontal pose is available, the soft biometric traits embedded in the face such as mole, scar, freckles make a significant contribution in the face identification as they carry some ancillary information of an individual[2]. Primary face recognition system with these features has a better identification accuracy rate[2]. Identification and verification of a human face through facial moles along with other primary facial features can be used in many security applications like issuing driving license, passport to international travelers, identification of wanted criminals and suspected terrorists[3]. This proposed system also can be used in airports, railway stations, public places and VIP areas for surveillance purpose.

Recently, researchers have investigated the use of facial marks for person identification under varying lighting and pose conditions. A. K. Jain and U. Park[2], U. Park and A. K. Jain[5] have used the LoG operator to detect facial marks for face recognition. Z. H. Choudhury and K. M. Mehata[6] have used SURF operator to detect facial marks covered under cosmetics for face recognition. J. S. Pierrard and T. Vetter[7] have performed NCC (normalized cross-correlation) with LoG template for detection and validation of moles for human identification. Ramesha K. et al.[8] also have performed NCC with complement of Gaussian template for the mole detection.

In this paper, a novel method is proposed for detecting and validating prominent moles present on the human face. The overview of the mole detection procedure is illustrated in Fig. 1. To improve the accuracy of the mole detection system, the affect of poor illumination on the face is reduced first and finally, after detection of mole candidates using normalized cross correlation, skin segmentation is done. In order to get better accuracy, a threshold based step is introduced as a contributory step of this paper. In this step, a threshold value, based on mole shade is set to filter the actual mole candidates. The paper is organized as follows. The creation of 'DeitY-TU' face database and the analysis of facial marks in 'DeitY-TU' face database is briefly described in Section 2; Section 3 provides the overview of the mole detection process. Finally, Section 4 concludes this work.

2. Creation of DeitY-TU Face Database

The DeitY-TU face database[9,16] is created in the Biometrics laboratory of Department of Computer Science & Engineering of Tripura University (TU), India. It consists of total 49,780 face images of 524 individuals from five different states of North-Eastern India[9]. All the face images are captured under strictly controlled conditions of lighting and poses. This face database contains total eight expressions including neutral, closed eye, anger, laughter, sad, surprise, fear and disgust; four different types of illumination variations (Full illumination, Half illumination, Left-Light-On and Right-Light-On) and images with glasses. Each of these variations is being clicked concurrently from five different angles ($+50^0$, $+25^0$, 0^0, -25^0, -50^0) to give pose variations[9]. Thus, this face database is created with combined challenges of illumination, expression and poses variations. For each person, total 95 images have been collected[9,16].

2.1. Statistical Analysis of Facial Marks in DeitY-TU Face Database

To investigate the viability of utilizing facial marks for person identification, a statistical analysis of facial marks in DeitY-TU face database is made. In many face images of DeitY-TU face database, presence of some soft-biometric characteristics, especially moles, scars, freckles, has been noticed. Though these soft biometric features lack distinctiveness and durableness, but they provide some ancillary information about an individual which can be used in identity verification. A brief description of facial marks likes mole, scar and freckles which can provide some ancillary information about an individual's identity is given.

- **Mole** is referred to as typical pigmented spots formed due to clustering of melanocytes, which is responsible for skin coloration. Moles are often brownish in color, although some may be darker or skin colored. The size, shape and color of moles vary a lot and some raise irregularly and become large.

- **Scars** are the marks induced by the healing of damaged tissues or cut. It is an area of tissue that replaces normal skin after injury.

- **Freckles** are collection of concentrated melanin and often visible on people with fair skin tone. It is a set of dark brownish spots on the skin. The amount of freckles is genetic.

In DeitY-TU face database, many face images contain soft biometric features. Fig. 2 shows the distribution of facial marks among five different states of DeitY-TU face database, which indicates among all 3 types of facial marks, mole is the most common.

3. Facial Marks Detection

A technique to detect prominent moles present in the human face is presented in this section. Moles appear as a small significant area on the face and from a distance it appears as a small dark region of circular shape surrounded by a brighter area and its appearance remain same under varying illumination conditions[7]. In DeitY-TU face database, the face images of a subject are captured under two lighting conditions: half illumination and full illumination. The face images captured with half-illumination condition are suffered from shadow and application of blob detector directly on it may produce several false positives. Thus, the raw images are preprocessed before going to detect prominent moles.

3.1. Pre-processing of Raw Images

Face images, captured under poor lighting conditions are suffering from poor illumination and shadow. The mole candidates lying under the shadow affected face region are not clearly visible, and it degrades the performance of the mole detection system. Hence, before going to feed these low quality images to the mole detection system, the contrast of this shadow affected images have been enhanced using a very popular contrast enhancement technique known as histogram equalization. Histogram equalization improves the interpretability or perception of information contained in the image for the human viewers[4]. Based on the probability distribution of the input gray levels, remapping of the gray levels of the input image is done in histogram equalization[4]. Though this preprocessing step degrades the quality of the overall face image, but it increases the visibility of the mole candidates, which is the primary concern of this paper. Fig. 3 shows the original shadow affected images and their respective contrast-enhanced images.

Again the changes in skin luminosity create several severe problems in computer vision based systems. Face recognition systems are very sensitive to lighting directions[10]. Thus, variation of illumination has a negative impact

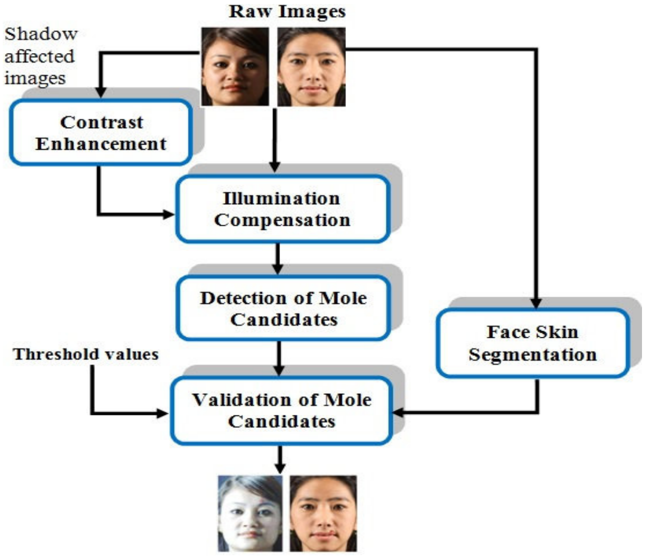

Fig. 1. Schematic diagram of the proposed Facial Mole Detection System.

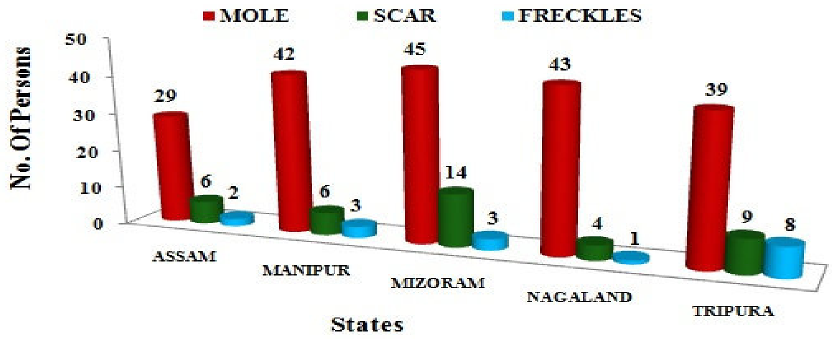

Fig. 2. Distribution of facial marks in DeitY-TU face database.

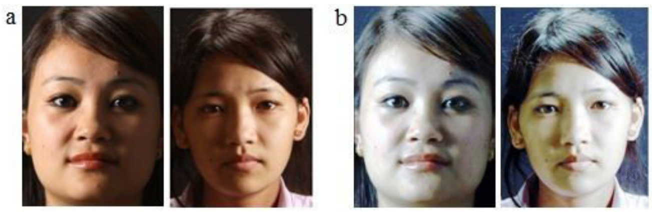

Fig. 3. (a) Original shadow affected images; (b) Contrast enhanced images.

on the performance of the mole detector. Hence, before applying mole detector directly on the raw images, it is very crucial to reduce the affect of illumination in the face images. In this work, Homomorphic filtering is used[11] to reduce the affect of illumination variation on face images. The illumination compensation of the original and contrast enhanced image is shown in Fig. 4. In Homomorphic filter model, an image is represented as the product of two components: i) the amount of light incident on the scene being viewed, I(x, y); and ii) the amount of light gets reflected from the objects on the scene, R(x, y)[11]. Thus, an image F(x, y) is represented as given in equation (1) -

$$F(x, y) = I(x, y) * R(x, y) \tag{1}$$

Homomorphic filter reduces the significance of I(x,y) by considering that I(x,y) have more low frequency components than R(x, y)[11]. To attain this, the filtering process is executed in the frequency domain[11]. But these two components illumination I(x, y) and reflectance R(x, y) are combined multiplicatively. Hence, before transforming them into the frequency domain, these components are made additive by applying natural logarithm to the original image[11]. After performing Homomorphic filter, exponential of the output image is performed to get back the illumination compensated image.

From Fig. 4(b), it is comprehensible that the effect of poor illumination cannot be removed completely from the shadow affected images by using Homomorphic filter. However, in the contrast-enhanced face image in Fig. 4(c), the Homomorphic filter gives a better result in making the illumination uniform.

Fig. 4. Illumination Compensation of (a) Original raw face image; (b) Shadow affected image; (c) Contrast Enhanced Image.

3.2. Mole Detection

The raw face images after preprocessing are used for detecting prominent mole candidates. The mole candidates are detected by using a template matching method called normalized cross correlation (NCC)[7,8]. Correlation is a significant tool for feature detection in an image. Normalized cross-correlation is the simplest, but effective method for finding the similarity score between the template and the given image[12]. The cross correlation between two images is measured by squared Euclidean distance[12]. Mole appears as a small dark region of circular shape surrounded by a brighter area i.e. it looks like a blob. To detect such blob like structures, Laplacian of Gaussian (LoG) filter is used as the template[7]. Laplacian filters are second derivative filters used to find areas of rapid intensity changes i.e. edges. However, this derivative filter is very sensitive to noise. Hence before applying Laplacian filter, the image is first smoothed by using Gaussian filter to reduce its sensitivity to noise. Thus, LoG is the combination of Laplacian and Gaussian filter. The LoG filter is represented by the equation (2) -

$$LoG(x,y) = \nabla^2 G(x,y) = -\frac{1}{\pi\sigma^4}\left[1-\frac{x^2+y^2}{2\sigma^2}\right]e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{2}$$

Where, σ is the standard deviation. Amount of smoothing of Gaussian filter depends on the value of σ. Higher the value of σ means higher the amount of smoothing. However, the NCC is not scale invariant and the size of moles is not fixed[7]. Hence, five different size LoG templates are used in the experiment. In Fig. 5, detection of mole candidates using NCC is shown.

3.3. Skin Segmentation

Some typical facial features like nostrils, corners of eyes, eyebrows, mouth, eyes, and beards are also detected as mole candidates due to the sensitivity of the NCC detector. There are some face images in the DeitY-TU face database[9], where the subjects are wearing nose-ring, eyebrow jewelry, lip studs and bindi, which are also detected as mole candidates. However, these candidates are not discriminative across individuals, and they have a negative impact on recognition performance. Some sample face images and their respective normalized cross correlated image are shown in Fig. 6, where some false candidates are detected as moles. These false candidates are manually marked in the NCC images in Fig. 6. Hence, in order to detect the actual mole candidates, these false mole candidates must be rejected. For this, the face skin needs to be segmented into skin region and non-skin region. After performing segmentation, all the mole candidates lying outside the skin-region can be rejected. In order to segment the human skin region from non-skin region based on skin color, a reliable color model or skin detector is required which can discriminate between skin and non-skin pixels for a wide range of people with different skin type. The RGB color model is not suitable for characterizing skin color due to its sensitivity to illumination change[13]. Moreover, in RGB color space chrominance and luminance are mixed and they cannot be separated. Here in this work, YCbCr color space is chosen for skin segmentation, where luminance Y and chrominance components Cb, Cr are separable, which makes it better for skin segmentation[13]. A threshold based segmentation technique in YCbCr color space with threshold values for Y, Cb and Cr[14], has been used for segmenting the facial skin. Fig. 7 shows the skin segmentation of some sample face images.

Fig. 5. Detection of moles using NCC with LoG filter.

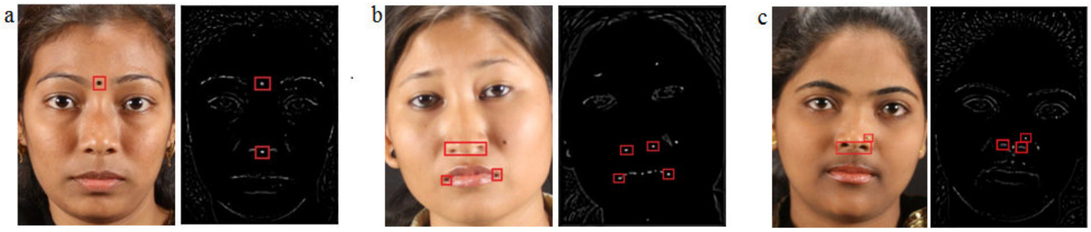

Fig. 6. False Detection of (a) bindi; (b) Corner of mouth, nostrils; (c) Nose ring, nostrils as mole candidates.

3.4. Validation of Prominent Moles

After detection of mole candidates using normalized cross correlation, their coordinates are used for validation purpose. These coordinates are then compared with the segmented image[8]. The coordinates lying in the non-skin region of the segmented image are rejected as they are falsely detected as mole candidates. For all remaining mole candidates, a predefined NCC threshold value is set to consider only those moles which are sufficiently prominent and significant for human identification purpose. Fig. 8(a) shows the comparison of NCC image and segmented image for finding out the mole candidates (manually marked) lying in the skin region of the face. The detection of actual mole candidate is shown in Fig. 8(b) and Fig. 8(c) shows the detection of mole in contrast enhanced image.

However, in DeitY-TU Face database, some face images are available in which acne like lesions present in the skin region of the face. Due to the sensitivity of NCC, these lesions are also detected as moles. Segmentation cannot separate these lesions from skin regions as they are lying in the skin region of the face. So for those images along with segmentation a threshold based method is used to validate the prominent moles. The threshold value is set based on the shade of the moles. The detected mole candidates are then compared with this threshold value and mole candidates having the itensity value less than that threshold value are detected as the actual prominent moles. The detection of moles in such images is shown in Fig. 8(d). The threshold values used for skin segmentation are not effective for contrast enhanced images for which, the contributory step introduced here is mendetory for those contrast enhanced images to detect the actual mole candidates.

3.5. Experimental Results

In this section performance analysis of our proposed mole detection algorithm is made in terms of accuracy and execution time. The parameters true positive (TP), false negative (FN), true negative (TN) and false positive (FP) have been used for performance evaluation. We first analyze the performance of our algorithm using our own developed DeitY-TU database which includes face images of varying illumination. The performance of the proposed method has been also measured with the face images of FEI face database[15].

- **DeitY-TU Face Database:** Total 120 face images (of 120 subjects) from DeitY-TU face database have been used to create a testing dataset. This dataset contains face images with and without mole. Required parameters for performance measuring are listed in Table I. The proposed system has an accuracy rate 91.67% with 4.16% false negative and 4.16% false positive. The false negatives are due to poor illumination on face images.

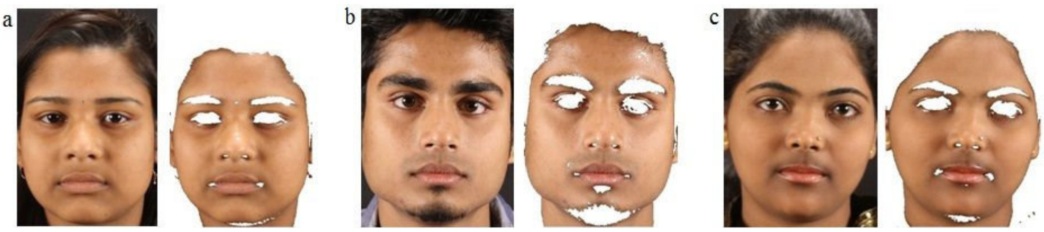

Fig. 7. Skin segmentation of face images (a) wearing a bindi; (b) having beard; (c) wearing nose ring.

Fig. 8 (a) Comparison of NCC image and skin segmented image; (b) Detection of prominent mole present on face; (c) Detection of mole in a contrast enhanced image; (d) Detection of mole in an acne prone face.

- **FEI Face Database:** Total 85 face images (of 85 subjects) with mole and without mole are taken from FEI face database[15] for performance evaluation. The required parameters for measuring performance are listed listed in Table 1. The proposed system has accuracy rate 90.58% with 7.1% false negative and 2.4% false positives. The false negative is due to the color, size and saliency of the mole candidates. The proposed method is a template based technique for which the template used to detect one mole may not be successful to detect another mole.

The comparison of accuracy rate and error rate for both DeitY-TU and FEI face database are shown in Fig. 9, which reflects that the proposed work is effective in both of the face databases. Fig. 10 shows the detection of moles in some sample face images of DeitY-TU and FEI face database.

Table 1. Required parameters of DeitY-TU and FEI face database for accuracy measure

Face Databases	DeitY-TU	FEI
Total Face Images	120	85
TP	80	59
FN	5	6
TN	30	18
FP	5	2
Computation Time (in sec)	3-4	2-3

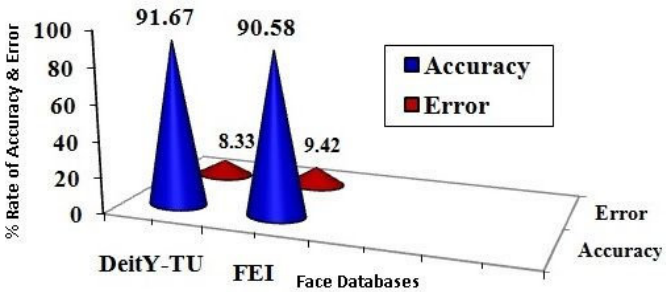

Fig. 9. Comparison of accuracy rate and error rate of DeitY-TU and FEI face database.

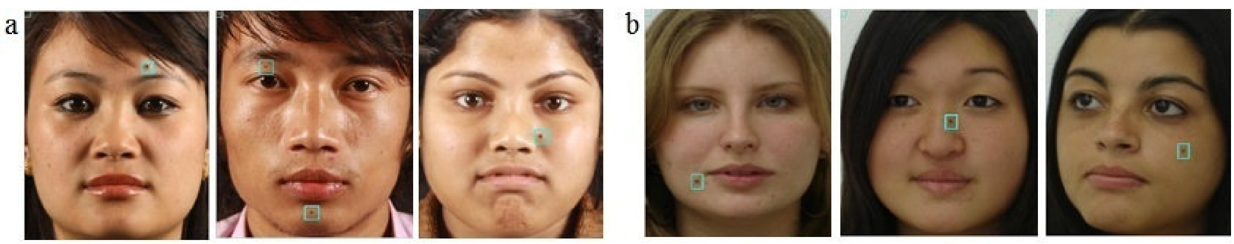

Fig. 10. Detection of moles in face images of (a) DeitY-TU and (b) FEI face databases.

4. Conclusion and Future Work

This paper presented a novel mole detection scheme in varying illumination. Implementation of contrast enhancement for shadow affected face images and illumination compensation for all face images allow this mole detection technique to cope up with the low illumination problem. The proposed system has experimental rate greater than 90% for both DeitY-TU and FEI face databases. The experimental results of both DeitY-TU and FEI face database reveal that the system works extremely well for the images whose face are full, upright and taken under varying illumination conditions. The scheme may be used with other primary features to identify a person more accurately.

Further code optimization will significantly speed up the process. In future, we are emphasizing on: a) detection of other facial marks like scars, birthmarks and b) face image retrieval based on facial marks.

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