Face Tampering Detection from Single Face Image using Gradient Method

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Abstract

An effective novel approach of detection and classification of real face image from tampered face image based on second order gradient is proposed in this paper. The intended purpose of proposed approach is to endorse the biometric authentication, by joining the vitality awareness with Facial Recognition Technology (FRT). The proposed method requires only one face image without requirement of additional equipment and easier to implement into existing face recognition technique. For this purpose, real (from own database and some publically available standard database) and tampered (own prepared databases of dummy, color imposed and masked faces) face image database are used here for verification and validation of our assertion. The technique is novel technique and obtained results are initial results which are obtained after applying gradient method and demonstrate that the methodology is very well suited for the discrimination of image of tampered face from the image of real face with accuracy ranges 82.7% ~ 91.7%. This reliable way to detect the mala-fide attack is needed to robustness of the system and it will be able to solve very big real problems of the society when induced in automatic authentication system.

Keywords: *Vitality, spoofing, liveness, dummy face image, gradient method, colour imposed face and masked face images*

1. Introduction

Security is the prime concern in information processing, law enforcement, surveillance and commercial applications. In comparison with traditional knowledge based authentication methods i.e. password and PIN: biometrics plays an important role. Biometric technology is one of the most rapidly developing segments of information technology and more outstanding use of it for security application is expected. Face always plays an ethical role in human interaction compared to other biometric traits. The face image is most popular non-intrusive and non-invasive biometrics whose image can easily be snapped without user co-operation [1].

The available literature bears the witness that the most of researches belonging to Facial recognition technology (FRT) starts with the feature extraction of probe face image without considering face image tampering in their application. For security concern, research must focus in the direction of accurate classification of image of real face from the image of fake or tampered face image using single image because most of the time single face image of criminals or imposters could be available from crime scene. If captured image from dynamic scene is image of real face then it needs to go to FRT otherwise switch towards other forensic techniques for criminal’s identification without wasting the time in wasting the time for FRT.

Techniques by which the imposters cheat the authentication system by presenting the fake biometric are known as vitality. In last decade, some techniques have been discovered to detect the face vitality by using multiple face images [5, 6, 20, 21 and 22] or frames extracted from video [7]. Even depth information has been considered to classify the real face image from photographic image of targeted subject because depth map is constant in the case of photograph and live face yields various depth values [4]. Most of the researches have contributed in vitality or liveness detection but none of them has achieved the expected adequate maturity level till now. That's why antisocial elements, hackers, imposters and criminals have developed so many types of mechanism to mislead the authentication systems and most of the time they escape.

In spite of a lot of available mechanisms to tamper the face, imposters use mostly mask, disguise, dummy and plastic surgery to hide their own facial identity and commit the offence. To resist these types of attacks and demoralise the act of criminals and hackers, this research has been contributed. It is the novelty of proposed method as it uses single face image of uncontrolled environment for tampering detection using gradient method. The methodology of tampering detection explores the property of organisation of human skin and detects the tampering. This technique is based on the gradient vector of the human facial skin and extracts the features of the surface. When the targeted facial skin is tampered, the proposed technique will produce a very discriminating feature values than that of real face. At last Support Vector Machine (SVM) is used to classify the image of real face from the image of tampered face. The reliable way to detect the mala-fide attacks is crucial for robustness of the system.

This paper is organised in seven sections. Section 2 includes related work and Section 3 contains database acquisition while Section 4 includes pre-processing of acquired database. Section 5 is proposed methodology for vitality detection and Section 6 contains experimental evaluation, results and analysis. Finally Section 7 is conclusion and future scope.

2. Related Work

So many literatures are available for face liveness and vitality detection. Without spoofing measurement the advancement in FRT is defenseless to attack. In most of the state-of-the-art in facial biometrics, researchers maximize the discrimination of facial identity rather to check the real or live face image. Following literatures are available for face liveness or vitality detection.

To distinguish the image of live face from still photograph of same person, Choudhury T., *et al.,* [4] presented depth information evaluation from both real person and his or her photograph. There is another technique available to estimate the depth information for the classification of live face image or recaptured photograph because depth map is constant in the case of photograph and live face yields various depth values [4] but it is not easy to estimate depth information when head of the person is in stationary position. There is another challenge to get depth information. To get depth information, camera should be very sensitive to light. Therefore, noise and lighting condition will also present adverse effect in data acquisition.

K. Kollreider, *et al*., [2] demonstrates to get the occurrence of non-rigid deformation and appearance change such as mouth motion and expression variation etc. They evaluated optical flow from targeted image sequence to measure the face motion information. This technique requires multiple image sequence, high quality image and user co-operation to obtain required motion information.

Not only from single modal, multimodal approach against face spoofing are also described by [14, 15]. They exploited the lips movement during speaking. Face together with voice is considered to obtain face spoofing. In this technique an additional hardware (voice recorder) and user co-operation are needed for data acquisition.

Li, *et al.*, [3] explored the high frequency component using Fourier Spectra and found that high frequency component of photographs is less than that of live face image because recaptured photographs are smaller in size and produce less high frequency components than real live image. This technique is applicable for less sampled or low resolution photographic images but will not produce expected results for high resolution (quality) photographic image. Multiple face images is needed for liveness evaluation.

Facial thermo-gram is also applied by Socolindky D. A., *et al.*, [16] for liveness detection using thermal infrared camera. Therefore,very costly camera and user co-operation are needed.

Eyes blinking based approach have also been explored by [17, 18] for live face detection. Eyes blinking are physiological phenomena. Rapid closing and opening of eyelids are measured with the help of comparison of two or more image sequence but most of the people don't open their full eyelids at normal vision. Therefore, high user co-operation is needed for data acquisition that camera would be placed at same horizontal level that of eyes which is not easy to setup the camera at public places as different people may have different hight.

Tan X., *et al.*, [19] explored the Lambertain reflectance to differentiate the 2D image of face print and live 3D face image by using retinex-based and Gaussian-based approach. The technique extracts the latent reflectance features and then classifies the live 3D face image from 2D face photograph image. But in the case of tampered face this technique will not produce differentiating results because tampered face is already 3D face. Hence the objective of face liveness detection doesn't meet at satisfactory level.

J. Bai, *et al.*, [23] modelled the captured image or frame extracted video by Bidirectional Reflectance Distribution Function (BRDF). BRDF is decomposed into specular components and diffuse components. Then dichromatic model is created. Then classify the recaptured face image with live face image by using linear SVM. [24] also extracted same physics based technique for liveness detection.The vein map of face image can also be used for liveness detection using ultra-violet camera is also a secure method but it requires a very special and costly camera.From single face image J. Maata, *et al.*, [25] represents the face image spoofing detection using texture and local shape analysis to detect the playback photo attack.

The above literature evidences that very less stimulation has been contributed to detect the face spoofing effect from single face image. Hence this research has been done to solve very big real social problem.

3. Database Acquisition

To validate the effectiveness of our proposed technique, we have prepared four types of heterogeneous database using simple 12.2 megapixels, 5x optical stabilised camera. The images have been taken at a distance of nearly 24 cm. to 30 cm. in an uncontrolled environment. The captured images are natural images without imposing any constraints neither on the targeted subject nor their surrounding like background, illumination etc. More than 10 months of time have been spent for the database preparation. Samples of obtained face images are shown in Figure 1.

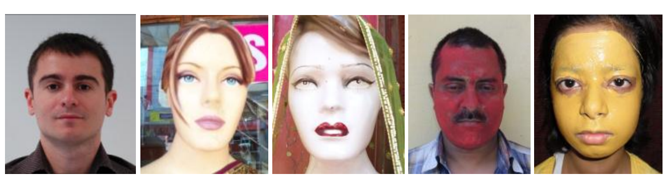

Figure 1. Sample Face Images

3.1. Database Profile

Benchmark standard database are highly essential for research work. Unlike face recognition, no standard benchmark database is available in public domain for tampering detection. Therefore, we have made our own protocol and prepared two types of database: Real face image database and tampered face image database.

i) **Real Face Image Database-** We have collected 100 publically available PIE, AR and Yale B face image database. Own real face image database have also prepared, in which 150 volunteers have taken part and we have captured 10 poses of each subject from the camera positions are shown Figure 2 and sample images are shown in Figure 3.

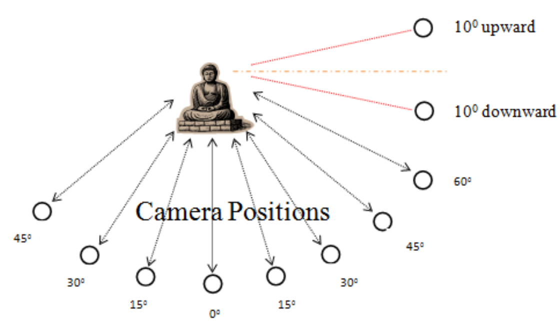

Figure 2. Camera Positions for the Pose Variation (*Adopted from [8]*)

Figure 3. Pose Variation of Captured Dummy Face Images (*Adopted from [8]*)

ii) **Tampered Face Image Database-** In the category of tampered face image three types of databases is acquired.

- *Dummy Face Image-* To get 100% tampered face we have acquired 200 dummy face images which are bifurcated as 120 females and 80 males. Dummies are available at various public places where any controlled constraints like illumination and camera stand etc. will never possible to impose either on targeted subject or their surroundings. Acquired dummy face images are natural day light images. The targeted subjects are always affected by the illumination of weather condition. Sample dummy face images are shown in Figure 4.

Figure 4. Sample Dummy Face Images

- *Colour Imposed Face Image*- Colour imposed face images of 90 volunteers described above are acquired by applying synthetic colour on facial surface. 60 volunteers were not convinced to tamper their faces. Hence only 90 subject's colour imposed face images are acquired for database at said protocol. In this category, database of each subject with nearly 100%, 60% and 30% tampering of face surface are acquired to evaluate the performance of proposed methodology. The sample colour imposed face images are shown on Figure 5.

(a) (b) (c)

Figure 5. Colour Imposed Face Images (a) Nearly 100%, (b) Nearly 60% and (c) Nearly 30% Tampered

- *Masked Face Image*- Only 120 volunteers out of 150 were convinced for masked face photo session. For masked face preparation, a cosmetic cream is used whose effect is equivalent to mask when imposed on the facial skin. In this category, database of each subject with nearly 100%, 60% and 30% tampering of face surface are acquired. The sample masked face images are shown on Figure 6.

(a) (b) (c)

Figure 6. Masked Face Images (a) Nearly 100% tampered, (b) Nearly 60% and (c) Nearly 30% Tampered

4. Pre-processing

The purpose of normalization is for the alignment of acquired database with illumination compensation. Due to the alteration of illumination, the appearance of image changes which are real challenges in FRT. The steps involved in normalization process are shown in Figure 7.

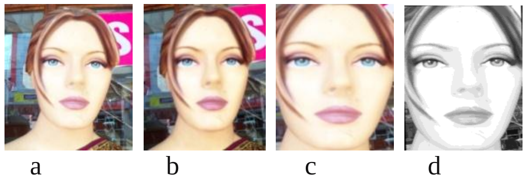

Figure 7. (a) Original, (b) Rotated, (c) Cropped and (d) Illumination Compensation

4.1. Database Normalisation

Gross, *et al.*, [5] describes the illumination with pose variation. Likewise, our database is also captured during day time in outdoor environment which are affected by change of lighting due to weather condition. The shadow of subject appears due to extreme light which also diminishes certain facial features. Moreover, extreme lighting can also produce too bright images, which can affect the automatic recognition process [9]. In our case, we have used *normalization and pre-processing* approach [10] for illumination compensation because the algorithm, of this category doesn't requires any training and modelling steps.

Illumination Plane Subtraction with Histogram Equalization- The illumination plane $IP(x, y)$ of an image $I(x, y)$ corresponds to the best-fit plane from the image intensities. $IP(x, y)$ is a linear approximation of $I(x, y)$ given by:

$$IP(x, y) = a.x + b.x + c \tag{1}$$

where coefficients a, b and c are described in multiple linear regression rely on the independence of model terms. When terms are correlated and column of design matrix N have an approximate linear dependence, the matrix $(N^T N)^{-1}$becomes close to singular and estimated as:

$$p = (N^T N)^{-1} N^T x \tag{2}$$

which becomes highly sensitive to random errors in the observed response x, producing a large variance. Thus the situation of *multicollinearity* can arise. For example, when data are collected without an experimental design. Now $p \in \beta^3$containing the plane parameters (a, b and c) and $x \in \beta^n$ is $I(x, y)$ in vector form (n is a number of pixels). So, $N \in \beta^{nx3}$ is a matrix containing the pixel coordinate: the first column contains horizontal coordinates, second column vertical coordinates and third column has all values fixed to 1 because images are 2D images.

After estimating $IP(x, y)$ resultant image $R(x, y)$ is obtained as-

$$R(x, y) = I(x, y) - IP(x, y) \tag{3}$$

This mechanism compensates the shadows due to extreme light angles and then histogram equalization is applied for the brightness compensation of the images as shown in the Figure 8 and Figure 9.

In Figure 8 it is clearly visible that if the illumination in gray scale image is high, normalization process reduces the illumination. Similarly in Figure 9 the normalization process improves the illumination.

Figure 8. (a) Original Dummy Image (b) Gray Scale Dummy Image (c) Dummy Image after Normalization: Illumination Reduces

Figure 9. (a) Original Dummy Image (b) Gray Scale Dummy Image (c) Dummy Image after Normalization: Illumination Improves

4.2. Database Image Compression

Experiment 1: In this part all normalized images are compressed from L_0 of size 250x300 pixels into three compression levels L_1, L_2 and L_3 in which dimensions of images of each successor level is half (50%) compressed from previous level image. These compressed images are obtained by applying Gaussian operator [12]. Gaussian pyramid consists of low pass filtered reduced density images of previous level pyramid image. Original level is known as base image. If $F_0(x, y)$ is original image

$$G_0(x,y) = F_0(x,y) \; for \; level \; l = 0 \tag{4}$$

$$G_l(x,y) = \sum_{m=-2}^{2} \sum_{n=-2}^{2} w(m,n).G_{l-1}(2x+m)(2y+n), \;\; Otherwise \tag{5}$$

Where $w(m, n)$ is 2D Gaussian kernel which has the properties as separable, symmetric and contributes same weight difference from next node for example {1 4 6 4 1}. These levels of images contain the texture information of holistic image of real as well as tampered face. Samples of compressed images are shown in Figure 10.

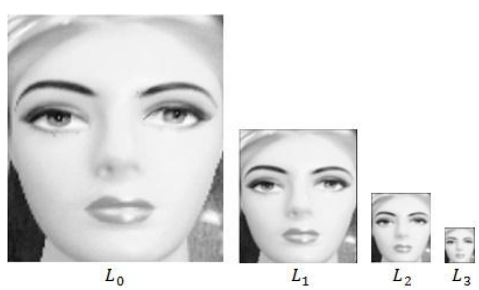

Figure 10. Original L_0 and Compressed L_1, L_2 and L_3 Face Images

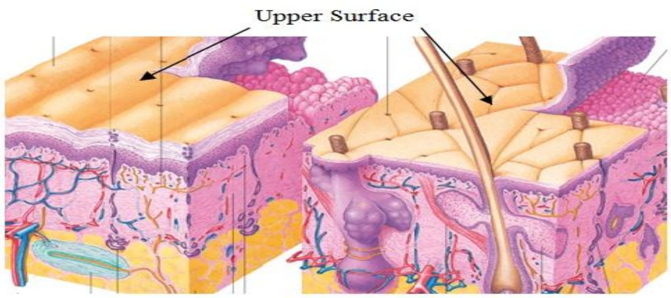

Figure 11. The Organization of Skin (*Adopted from [11]*)

5. Proposed Methodology

It is revealed from Figure 11 that the upper surface of human skin is not very smooth [11]. Skin surfaces are intrinsically coarser than artificial materials used to tamper the face with cosmetic materials, synthetic colours, face mask and dummy faces. Face mask is generally used by criminals to hide their facial identity, is made of rubber which after stretching becomes very smooth than skin. Dummy faces are made of plastic material which is also very smooth. Cosmetic materials are generally used to fill-up the wrinkles and coarseness of facial surface.

For the feature extraction of skin surface, second order gradient method is applied on both real and tampered face normalised images.

$$\nabla = \frac{\partial}{\partial x}.i + \frac{\partial}{\partial y}.j + \frac{\partial}{\partial z}.k \tag{6}$$

$$\text{Gradient} \quad \nabla.f = \frac{\partial f}{\partial x}.i + \frac{\partial f}{\partial y}.j + \frac{\partial f}{\partial z}.k \tag{7}$$

Second order gradient (*Dot product of two gradient vector*)

$$\begin{aligned} \Delta.f \triangleq \nabla^2.f &= (\nabla.\nabla).\mathrm{f} \\ &= \left(\left(\frac{\partial}{\partial x}.i + \frac{\partial}{\partial y}.j + \frac{\partial}{\partial z}.k\right).\left(\frac{\partial}{\partial x}.i + \frac{\partial}{\partial y}.j + \frac{\partial}{\partial z}.k\right)\right).f \\ &= \frac{\partial^2 f}{\partial x_2}.i + \frac{\partial^2 f}{\partial y_2}.j + \frac{\partial^2 f}{\partial z_2}.k \end{aligned} \tag{8}$$

For the two dimensional face image-

$$F = \Delta f = \frac{\partial^2}{\partial x_2}.f(x,y) + \frac{\partial^2}{\partial y_2}.f(x,y) \tag{9}$$

F is overall second order gradient feature of image $f(x,y)$.

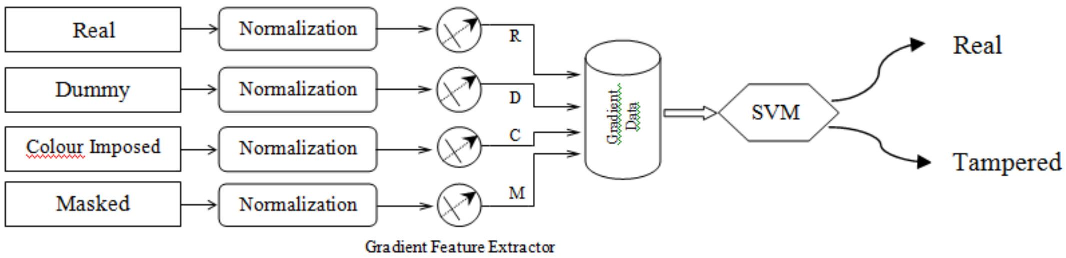

Figure 11. Block Diagram of Proposed Method

6. Experimental Evaluation

6.1. Experimental Protocol

In this paper three experiments are prepared:

Experiment 1: Second order gradient features of original and compressed images are evaluated with proposed technique and obtained the feature values which are shown in Table 1 and Figure 12.

Table 1. Gradient Features of Original and Full Tampered Face Images

Compression Levels	Public Real Database	Own Real Database	Dummy	Colour Imposed	Masked
L_0	0.9365	0.9543	0.9903	0.9738	1.0100
L_1	1.0589	1.1231	1.2980	1.1680	1.2015
L_2	1.0972	1.2168	1.5376	1.2898	1.3600
L_3	0.7010	0.7460	1.6361	1.2073	1.3476

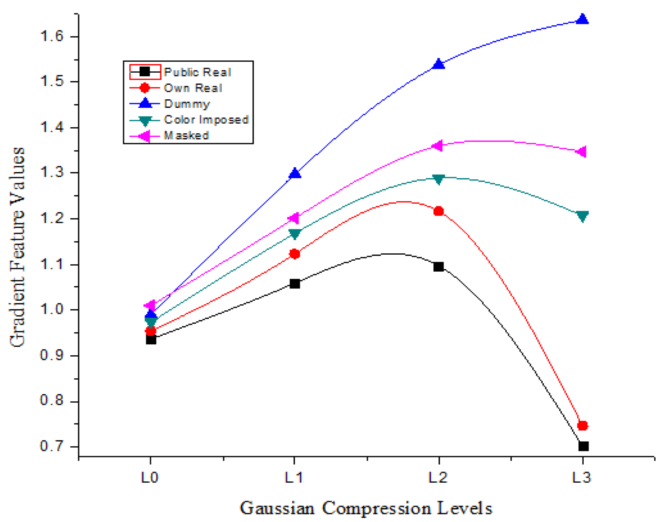

Figure 12. Graph of of Real and Full Tampered Face Image Gradient Features

Experiment 2: In this experimant, the proposed gradient features of original and partial tampered face images are obtained and results are shown in Table 2 and Figure 13. The real face of own database have only tampered.

Table 2. Gradient Features of Original and Partial Tampered Face Images

Compression Levels	Own Real Database	Colour Imposed		Masked	
		60% Imposed	30% Imposed	60% Imposed	30% Imposed
L_0	0.9543	1.0413	1.0099	1.0906	0.9944
L_1	1.1231	1.2387	1.1901	1.3020	1.1810
L_2	1.2168	1.2901	1.2705	1.3306	1.2465
L_3	0.7460	1.3057	0.9745	1.3401	1.0356

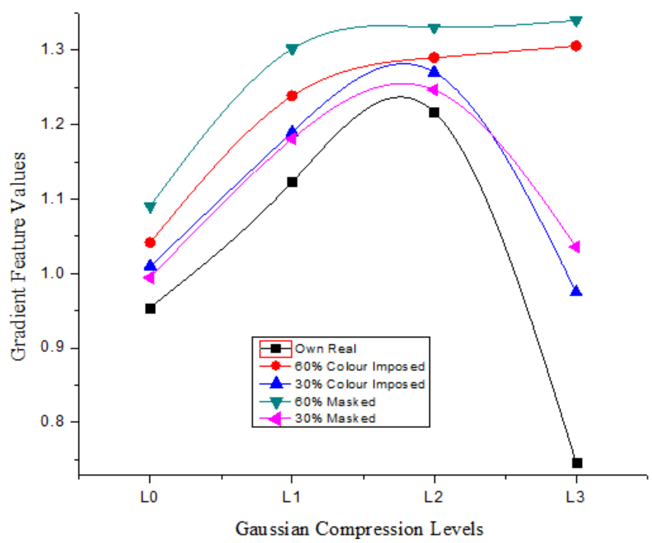

Figure 13. Graph of Gradient Features of Real Face Image, Partial and Full Tampered Face Image

Experiment 3: Three textures of the face images T_1, T_2 and T_3 for forehead, left cheek and right cheek respectively are cut. For the best results in our case, the size of these textures are 50x50 pixels. Obtained results in the form of gradient features of these textures are shown in Table 3 and Figure 14. These textures are cut by only real and full tampered images because when we cut the texture from partial tampered face image, the intertexture gradient features will already differ due to partial tampering.

Table 3. Gradient Features of Textures of Real and Tampered Face Images

Compression Levels	Public Real Database	Own Real Database	Dummy	Colour Imposed	Masked
T_1	0.9782	1.0135	1.0020	1.0015	0.9987
T_2	0.9673	1.0151	1.0115	1.0093	0.9969
T_3	0.9484	1.0840	1.0060	1.0099	0.9991

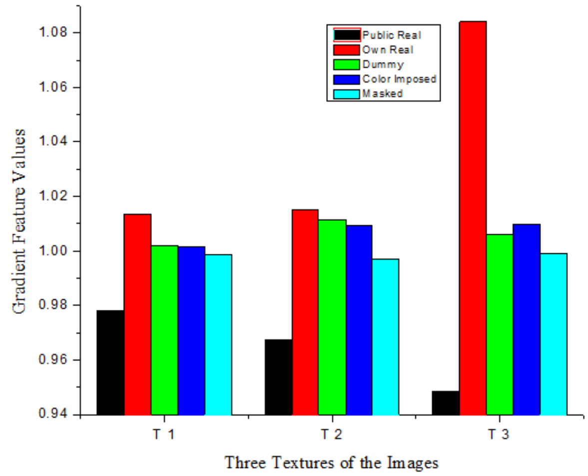

Figure 14. Graph of Texture based Gradient Feature for Real and full Tampered Face Image

6.2. Classification

To discriminate the tampered face image from real, SVM [13] is used to obtain the classification accuracy. The experiments are decomposed at various protocols. To train the classifier 60% images from each protocol are used. After training, threshold is chosen on Equal Error Rate (EER) and based on such value of threshold; test set is used for remaining 40% images to evaluate the final performance of classifier. The best results for classification of tampered face images from real face image are shown in Tables 4, 5 and 6.

Table 4. Performance Comparison for the Experiment 1

Image Compression Levels	False Acceptance Rate (FAR)	False Rejection Rate (FRR)
L_0	13.4	17.3
L_1	10.7	12.6
L_2	9.9	11.7
L_3	8.9	10.8
Overall L	10.4	12.8

Table 5. Performance Comparison for the Experiment 2

Image Compression Levels	60% Tampered Face Image		30% Tampered Face Image	
	FAR	FRR	FAR	FRR
L_0	10.3	11.7	17.3	18.6
L_1	9.8	12.2	14.4	16.1
L_2	15.6	16.4	15.8	17.5
L_3	8.3	9.5	9.2	11.4
Overall L	12.7	13.6	15.3	15.7

Table 6. Performance Comparison for the Experiment 3

Texture	FAR	FRR
T_1	10.9	11.4
T_2	12.6	14.1
T_3	11.6	14.8
Overall T	12.8	13.4

6.3 Experimental Analysis

Since proposed technique is novel and initial results are promising and encouraging. The classification accuracy of tampered face from real face image lies in the range of 82.7% ~ 91.7%. From the above experimental results following conclusions may be drawn.

- Since the database have been taken in open and outdoor environment. Therefore, it contains some noise and distortions in the form of dust particles which diminishes the gradient features. As we compress the images, some sort of distortions and noise are removed automatically due to which, in each experiment, the gradient feature values of compression level L_1 and L_2 are higher than original image level L_0.
- From the result of experiment 1, in level L_3, the original facial skin diminishes the gradient feature because skin coarseness is reduced in high level compression while for the tampered face, skin coarseness is already covered with artificial tampering material and surface become more smoother. Hence, in tampered skin, the gradient feature values have not altered as compared to real skin.
- It is demonstrated from experiment 2 that when tampering surface increases the gradient feature value also increases.
- It is clearly visible from experiment 3 that the gradient feature values of each texture of tampered face image is nearly equal where as for the real face image gradient of each texture are almost different. This difference is due to the tampering material which imposes equal effect on whole facial surface. Hence, textures of same real face are very different than textures of same tampered face.
- The technique explores the natural biological property of skin and classifies the tampered face image from real face image because it is not easy to tamper the face surface just equivalent to real face. Tampering always conceal the real face appearance which discriminate real face by this proposed technique.
- The proposed technique does not require the image of tampered face of the probe for training purpose. It automatically discriminate the images of real face from images of tampered face on the basis of the ranges of gradient values at various protocols.

7. Conclusion and Future Scope

The current available biometric authentication systems are very much vulnerable to spoofing attack. Criminals and imposters use this deficiency as a privilege and always commit the offence after tampering their facial surface by artificial means as described earlier. By exploring the human biological skin property this research contributes the detection of face tampering from single face image using gradient feature. This technique is purely software based without including any additional hardware and is best suited for real time applications.The proposed methodology is robust and non-intrusive. The observed accuracy for the classification of face image of tampered face from the image of real face lies in the range of 82.7% ~ 91.7%.

The excellent result also suggests that more complex high quality database at standard protocol are needed for future work. In current scenario, FRT is unaware of the tampering or vitality attack due to which innocent persons shall be liable for the act of others if imposter uses the mask of another person. We strongly believe that the ascribed approach can pave the path of future research in face recognition to address tampering and spoofing scenarios.

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