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Face Liveness Detection Based on Frequency and Micro-Texture Analysis

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Abstract— **Facial biometric system is a widely used approach in security industry. But face recognition systems are vulnerable to spoofing attacks which can be done by falsifying data using non-real faces and thereby gaining illegal access. An easy way to spoof face recognition systems is to use portrait photographs instead of the real person. Thus, Liveness detection is needed to make a system secure against such spoofing attacks. Inspired from the fact that the images taken from 2-D photographs and live faces are bound to have differences in terms of shape and detailedness, we present an approach based on frequency analysis and texture analysis by using frequency descriptor and Local Binary Pattern (LBP) respectively. Experiments which were done on publicly available database showed excellent results and can efficiently classify live faces and 2-D photographs.**

Keywords—Liveness Detection; Spoofing; Frequency Descriptor

I. Introduction

The need for security measures against spoofing attacks is the utmost concern of general public. Biometrics is the fastest growing segment of such security industry. Biometrics is the technology of establishing the identity of an individual based on the physical, chemical or behavioural attributes of the person [1]. Among various techniques, face recognition system is the one which has developed rapidly in recent years. But, in general, face recognition algorithms are not capable of differentiating portrait photographs from live faces which is a major security concern. Spoof attacks can be done in many ways such as presenting a photograph, portrait, masks, and video in front of the camera. A secure system needs liveness detection in order to guard against such spoofing. Liveness is the act of differentiating the feature space into live and non-living. Liveness detection allows a biometric system to differentiate real face from a photo thus reducing the vulnerability.

Spoofing attacks occurs when a person tries to gain access to a security system by providing false data in front of the camera. Using printed photographs instead of the real person is an easy and common way of gaining illegal access to a secured system. As shown in fig. 1, fake face images captured from 2D photographs may be visually very similar to the live face images. Fig. 1 illustrates some examples of the live face images and their corresponding fake images taken from their printed photographs. But fake face images lack texture richness as compared to the texture components of live face images due to the fact that live faces reflect light in a different way than that of a photograph. Moreover, sequential fake face images won't show any temporal changes in the facial appearance whereas, live human faces would depict changes in pose and expression which will result in changes in facial appearance.

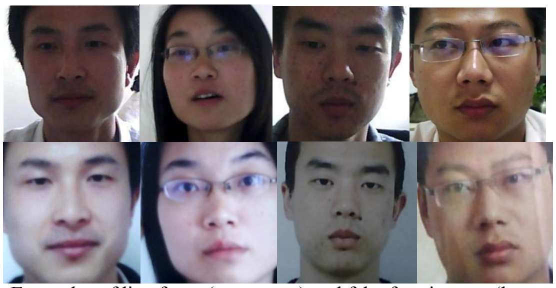


Fig.1. Examples of live faces (upper row) and fake face images (lower row)

In this paper, we propose a face liveness detection approach based on frequency and texture analysis for differentiating between live faces and 2-D photographs. For differentiating a live face and 2D photograph, we have used a thresholding operation based on the analysis of Fourier spectra and frequency descriptor. For analyzing the texture information, we have used Local Binary Pattern (LBP). The results of LBP are then fed to Support Vector Machine (SVM) classifier which determines whether the captured image is live face or not. Experiments done on publicly available database (NUAA Photograph Imposter Database) showed promising results.

In the next section, a discussion on related works on face liveness detection is presented. Our proposed approach based on frequency and texture analysis is then described in Section III. The experiment results were shown in Section IV. Finally, a conclusion is drawn in Section V.

II. Related Works

Without liveness detection, most of the face recognition systems are vulnerable to spoof attacks. Spoof attacks can be done by using a 2-D photograph, 3-D masks, video etc. A short survey of 2-D face liveness detection was done by Kahm et al. [2]. There are several liveness detection approaches based on the type of liveness indicator used to assist the liveness detection of faces. Some of the main indicators used are life sign, texture and motion. Jee et al. [3] introduced a technique based on the analysis of the movement of the eyes. The authors have detected eyes in sequential input images and then variation is calculated. Similarly, using life sign as an indicator, Pan et al. [4] introduced a technique of blinking-based liveness detection. They have used Conditional Random Framework (CRF) to detect eye blinking behaviour. Another technique using lip movement classification and face detection based on face landmarks was introduced by Kollreider et al. [5]. Support Vector Machine (SVM) was used for classification of lip dynamics once after recording the person speaking digits 0-9. Bao et al. [6] introduced a method based on optical flow field which analyzes the differences and properties of optical flow generated from 2-D planes and 3-D objects. Experiments were done on a private database which showed a 6% false alarm and 14% false acceptance. In a similar work [7], Kollreider et al. presented a method based on optical flow field and used it to capture the movements of different facial parts.

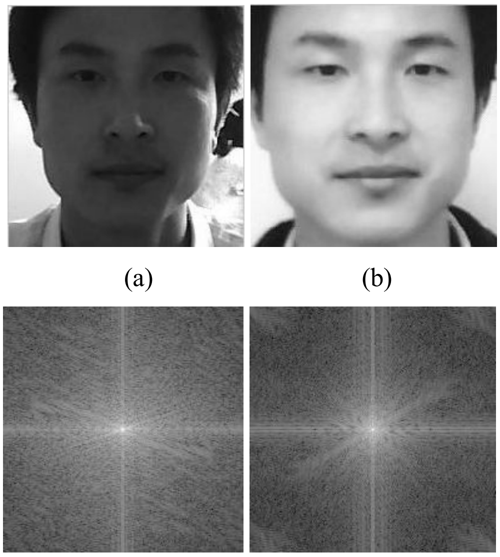
Another category of liveness detection is based on the analysis of texture. Li et al. [8] proposed a liveness detection approach based on the analysis of Fourier spectra of a single face image. Their method was based on the assumption that the size of the photo is smaller than that of the live face and frequency components of photo images is less than that of real face images. But the effect of illumination was ignored by the authors which would affect the results in a great way. In another work [9], Kim et al. proposed a technique using variable focussing. Based on the assumption that there is no movement, the authors utilize the variation of pixel values of two images taken sequentially in different focuses. Focused regions of real faces will be clear and blurred in case of fake faces. Their main constraint was that it relies on Depth of Field (DoF) which determines the range of focus variation.

The problem of anti-spoofing was introduced by Tan et al. [10] as a binary classification problem. The authors have used the Lambertian reflectance to differentiate 2-D face prints from 3-D live faces. By using a variational retinex-based method and difference-of-Gaussians (DoG) based approach, they extract latent reflectance features which are then used for classification. Another liveness detection technique based on 3D structure of the face was presented by Lagorio et al. [11]. Their method was based on the computation of mean curvature of the surface and the authors have showed that the surface variation is low when the image is taken from a 2-D source.

It has been observed that most of the liveness detection techniques are very complex and some of them use non-conventional devices and imaging systems. Our proposed method is computationally easy and fast and does not require the use of any non-conventional devices. Furthermore, it does not require any user cooperation.

III. Proposed Method

Live images which are captured from live faces may look similar to the fake images being captured from 2D photographs, photos etc. The expression and pose of the live face will vary in a sequential captured image sequence but in case of images captured from fake faces, the pose and expression will be invariant. Moreover, there is a difference in



(a) (b) (c) (d)

Fig.2. Difference between live face and fake face image in frequency domain: (a) live face image; (b) fake face image; (c) Log magnitude fourier spectra of (a); (d) Log magnitude fourier spectra of (b).

shape and detailedness which is caused by surface reflections and shades. In addition, the images taken from fake faces shows flat surfaces compared to live faces.

Our proposed method exploits frequency and texture based analysis to differentiate between images taken from live faces and that of fake faces (2D photographs, paper masks etc.). The main reason for using frequency based analysis is that the difference in shapes and detailedness of live faces and fake faces leads to the discrepancy in low frequency regions and high frequency information respectively (Fig. 2). The images captured from 2D photographs do not have that much of texture richness as compared to images captured from live faces [10]. Furthermore, there is a difference of micro-texture in the images taken from live faces and fake faces.

A. Frequency based analysis

In a sequentially captured image sequence, the pose and expressions of a live face will vary whereas, in case of fake faces, the pose and expressions will be invariant. An effective way to detect liveness is to monitor temporal changes of facial pose and expression over time. Facial appearance can be represented by an energy value defined in frequency domain. At first, four random images are selected from an input image sequence and a subset is constructed. The images are then transformed into the frequency domain by using 2D discrete fourier transform. An energy value of each image as defined in (2) in the subset is computed. The standard deviation of the resulting values, called frequency descriptor (FD), is calculated to determine the temporal changes of the face. The frequency descriptor is defined in (1).

$$\mathrm{FD} = \left(\frac{1}{\mathrm{n}} \sum_{i=1}^{n} \left(x_i - x_m \right)^2 \right)^{1/2} \qquad (1)$$

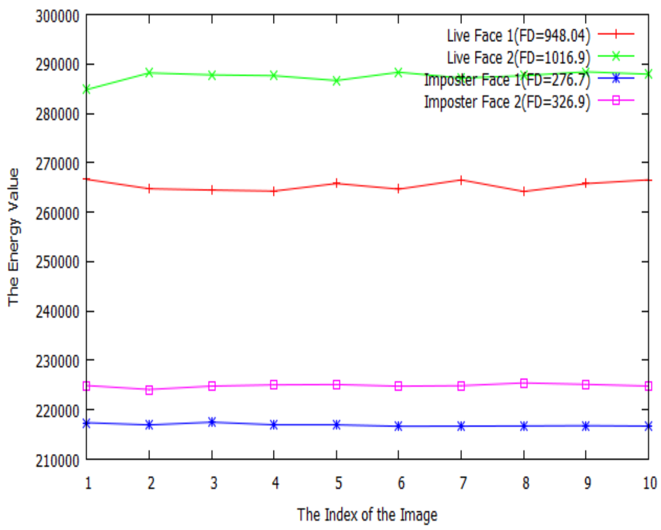


Fig.3. Energy value curves of four different images

$$x = \iint |F(u,v)| dudv \qquad (2)$$

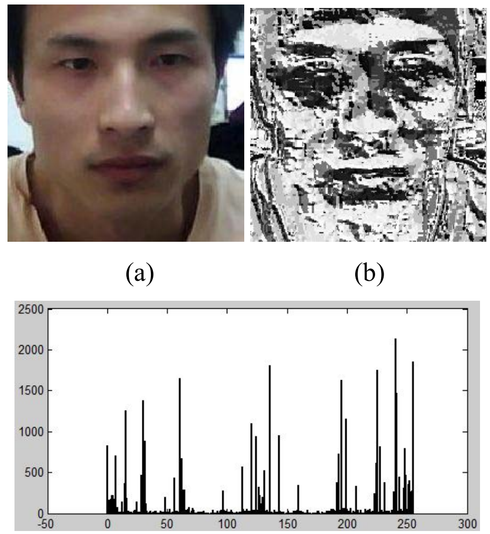
where, x_i corresponds to the energy of the ith image, x_m indicates the mean of the energy values and n denotes the total number of energy values. The energy value curves (fig. 3) of four different sequences of face image and their corresponding frequency descriptor shows that the energy and frequency descriptor of fake face image sequence are less than that of the image sequence of live faces. Thus, the frequency descriptor of live faces should be more than a threshold value t_{fd}.

B. Texture based analysis

The method based on temporal changes using frequency based analysis will fail if there are no temporal changes of facial appearance of the live face. Thus, we have also considered differences in micro texture. When the frequency descriptor of a facial image is higher than the threshold value, those images were passed on to the second part of the algorithm, micro-texture based analysis. For analyzing micro-texture differences of the images captured from live faces and fake faces (2D photographs), we have used the Local Binary Pattern (LBP). As introduced by Ojala et al. [12], the LBP texture analysis operator is a gray-scale invariant texture measure. It is one of the most popular and powerful method of texture description and some of its advantages are its discriminative power and its simplicity in computation. Equation (3) shows that by considering the relative intensity, the LBP assigns a code for each pixel and its neighbors.

$$LBP_{P,R} = \sum_{p=0}^{p-1} s(g_p - g_c) 2^p, s(x) = \begin{cases} 1, x \geq 0 \\ 0, x < 0 \end{cases} \qquad (3)$$

where, P corresponds to the number of neighboring pixels and R is the radius of the corresponding circle i.e. the distance from the center to the neighboring pixels. And, g_c and g_p corresponds to the grayscale value of the center pixel and the grayscale value of the p equally spaced pixels on the circle of radius R respectively and $s(x)$ denotes the threshold function of x. To analyze the micro-resolution texture, we have used various values of P and R. Finally, the values of P and R were set to 8 and 1, respectively.



(a) (b)

(c)

Fig.4. Feature vector extraction based on texture: (a) Live face image; (b) LBP coded image of (a); (c) Feature Histogram of (b).

The process of obtaining the feature vector of LBP from a given input image is shown in fig. 4. Fig. 4(a) depicts the original facial image and the LBP coded image of fig. 4(a) is shown in fig. 4(b). Fig. 4(c) shows the resultant feature histogram of fig. 4(b) which is being used as the feature vector for the classification. For classification, we have used Support Vector Machine (SVM) classifier with radial basis function kernel. To train the SVM classifier, we have used real faces as positive and fake faces as negative samples. Finally, it is used to determine whether the input facial image is live or not.

C. Algorithm

The flow chart of the proposed algorithm is shown in fig. 5. The proposed algorithm utilizes both temporal changes using frequency analysis and difference in micro-texture using LBP.

IV. Experiments and Results

A. Database

In this paper, we have used the publicly available NUAA Photograph Imposter Database. The database contains both real client images and imposter photographs. The database was collected using cheap webcams and in three sessions with about 2 weeks interval between two sessions. The illumination conditions of each session of the database are also different. The examples of both live face and imposter photograph images from the database are shown in fig. 1. The resolution of all the images in the database is of 640 x 480 pixels. The images were captured in a sequential manner with a frame rate of 20 fps and altogether of 500 images of each subject. For collecting photograph samples, high definition photos of each subject were taken using a Canon camera.

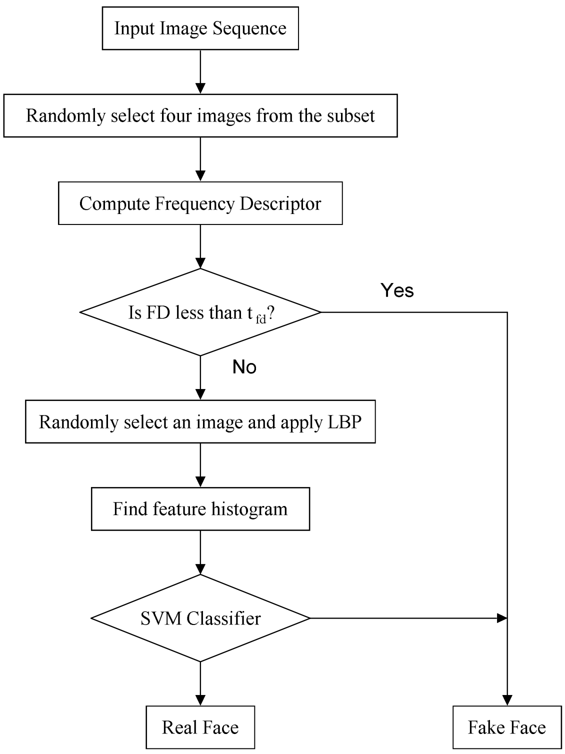


Fig.5. Flow chart of the proposed algorithm

B. *Experimental Results*

For the frequency based analysis part, we have considered the threshold value, t_{fd} = 600. In our experiments, the performance of the frequency descriptor was found to be very good and it was able to distinguish between fake faces and live faces quite well. The values of frequency descriptor of both live faces and fake face images are shown in table I. If the frequency descriptor of a facial image is higher than the threshold value, the images were analyzed on the basis of micro-texture difference. Now for the texture based analysis, we have divided the database into two parts for training and testing of SVM classifier. There were a total of 935 face images of real clients and 955 imposter images in the training set. The testing set was composed of 2875 real face images and 1050 imposter photographs. In all experiments of SVM, we have used LibSVM Library [13] for the implementation. We have also compared the method of LBP with previous traditional methods such as Local Phase Quantization (LPQ) and Gabor wavelets, the results of which are shown in table II. Table II indicates that Equal Error Rates (EER) of LBP is 2.7% which is less than that of LPQ (4.6%) and Gabor Wavelets (9.5%). Optimal SVM parameters were used for texture descriptor for fair comparison. Our proposed algorithm is also compared with the approach of Tan et al. [10]. Our approach performed well in comparison to the approach of Tan et al. (0.97 versus 0.94).

Table I. Results of Frequency Descriptors

Image	Frequency Descriptor		
	Min	*Max*	*Mean*
Live Face	712	1378	986
Fake Face	224	424	276

Table II. Performance Comparison between three texture operators

Descriptor	LBP	LPQ	Gabor Wavelets
Equal Error Rate (EER)	2.7%	4.6%	9.5%

V. CONCLUSION

In this paper, we have proposed a face liveness detection technique using frequency and texture based analysis. For frequency information, we have used an approach based on frequency descriptor and for micro-texture based differences; we have employed well known LBP technique for differentiating 2D photographs from live face images. The experimental results showed that our approach can efficiently distinguish between live face images and fake face images. The results of performance comparison with the previous works also turned out to be very good. In the future, we are planning to do liveness detection against video and 3D masks and the biometric system more secure against such spoofing attacks.

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