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Human off Angle IRIS Liveness Detection Based on Fusion of DCT and Zernike Moments

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Abstract: Liveness detection is the most important field in the field of biometrics. The development of biometric-based liveness detection algorithms provides a key role in the success of security applications. Liveness detection helps the system to identify whether the user is real or fake. Proposed Algorithm Provides novel approach of liveness detection based on the fusion of discrete cosine transform (DCT) and Zernike moments. Conjunctival vasculature which is a region of interest is a low-frequency image area. This makes DCT transform based feature extraction important for low-frequency feature analysis. Off angle iris database generation gets affected by the lightening effect. To overcome this drawback Zernike moments-based feature extraction is proposed. A combination of DCT and Zernike makes an innovative feature for an off- angle iris. Statistical features are used to test the accuracy of the system. It can be shown that the fusion approach performs better as compared with individual methods. The algorithm is tested by using Extreme Learning Machine (ELM). Equal error rate (EER) is calculated to test the robustness of the liveness detection system.

Keywords: Liveness Detection , Off Angle IRIS, DCT, Zernike Moments , Extreme Learning Machine (ELM) ,EER. … ,

1. Introduction

Biometrics is a method to recognize a person based on their behavioral characteristics. Several biometric traits have been developed and provide success in terms of their accuracy. Nowadays liveness detection plays a crucial role in the field of security. Among all biometrics, IRIS based algorithms proved better for checking liveness. But it has one major disadvantage. We require special hardware in terms of IRIS scanner which makes somewhat awkward for user. Also if the person has surgery for an eye then IRIS capture is not possible. The entire processing of IRIS is done NIR spectrum. Also, success totally depends upon the quality of IRIS images. Considering all these factors new modality arrived called conjunctival vasculature. It is the white-colored outer surface of an eye. Human off angle iris image is collected when user is looking towards extreme left or right direction away from camera lens If we capture an off-angle iris images this white portion can be explored for feature extraction. Also, this modality can be capture in the visible spectrum by using a simple digital camera. Researchers proved that some special properties of the conjunctiva can be useful for checking liveness. Blood vessel patterns in the human can provide unique information. This modality has an abundant number of blood vessel patterns that can be observed at multiple layers. This makes the system more robust and user-friendly. The rest of the paper is organized as follows. Section 2 provides work done in the field of conjunctival vasculature, while section 3 provides the methodology of the system. Further Section 4 provides a detailed explanation of the proposed algorithm. Section 5 provides deep analysis and discussion based on experimentation. Section 6 provides concluding remarks along with the future scope.

2. LITERATURE REVIEW

Conjunctival vasculature defines the white portion of the eye image. Due to the availability of the multi-layer structure of blood vessels pattern, it can play a significant role in the development of security algorithms. Conjunctiva was introduced as a biometric by Si1mona Crihalmeanu and Arun Ross [1].They highlighted important characteristics of conjunctiva so that it can be

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considered as a biometric modality. Although the conjunctiva is part of an eye image it can be easily capture without an eye scanner and lens.They also explore the multi-layer blood vessel pattern which plays an important role to identify fake identity. Also, different discontinuities in the blood vessels can provide features for liveness detection system implementation. Experimentation was carried out on multispectral eye images. They provide a methodology to extract conjunctival vasculature from these multispectral eye images. Minutiae patterns were extracted from conjunctiva which is the region of interest. HU invariant moments were used as a feature vector for identification. The accuracy of the system was found to be 100%. But the algorithm has few limitations. Experimentation was done only on 49 objects. Also, the segmentation of conjunctiva from eye image was done manually. Stephanie Schuckers used conjunctival vasculature for the development of a liveness detection system in [2]. They also succeed to prove the fact that conjunctiva along with IRIS improves system accuracy. The new algorithm in [3] was invented to separate blood vessels from an off-angle eye image. A local binary pattern (LBP) was used to find textural characteristics from every pixel in the conjunctiva. These features were used to identify the effect of diabetics on the conjunctiva. Again testing was done only on 40 conjunctival images. Fake IRIS was detected by using multiple wavelet filter banks in [4]. The methodology was used to check the portion near pupil boundary to find the exact size of pupil and iris in the presence of visible light. A fake iris database was created in [5]. The researchers explained in a depth procedure for the generation of a fake database. Real iris database was created by using a biosec scanner. Fake iris images were generated by presenting printouts in front of the iris scanner. They discussed the possibility of direct and indirect attacks on an iris image. They also highlighted the lightning effect at the time of generation of the database. Xinyu Huang, Changpeng Ti, Qi-Zhen Hou explored pupil properties like a constriction in presence of light to check liveness [9]. A fusion of iris and conjunctiva is used for experimentation in [10]. A database of 50 persons was used for experimentation. They found that an equal error rate was reduced by 4.5% due to fusion when compared with a system without fusion.

S.N.Dharwadkar, Dr.Y.H.Dandwate and Dr.Aditya Abhyankar make use of conjunctival vasculature for the development of a liveness detection system. They derived statistical features from the Discrete Cosine transform (DCT) coefficients [12]. A novel approach for automatic segmentation of conjunctiva from Off angle eye image was proposed. The algorithm was tested on 719 eye images. The database consists of 600 real and 119 fake off-angle eye images. Printed off-angle iris images were used as a fake database. A support vector machine classifier was used for accuracy testing. They have calculated an equal error rate (EER) for checking the robustness of the system against liveliness. In [13] the authors developed a new method for checking quality of sclera images. They were able to detect this quality automatically. Multi-directional Gabor Filters used for enhancement of vascular structure. In [14] methodology was employed to utilize multimodal biometric modality in the forms of the conjunctiva and peri-ocular region for human recognition. Local binary patterns were used as a feature vector for fusion. The algorithm was tested by using an extreme learning machine. They were able to achieve an EER of 0.38. UBIRIS V2 database was used for experimentation.

The fusion of iris and ocular biometrics was done by Crihalmeanu and Ross [15]. Segmentation was performed by using a selective enhancement filter. Minutiae patterns and affine transforms were used as a feature vector. Authors proposed a new fusion technique of different recognition approaches which is used for non-cooperative iris recognition [16]. Area outside iris along with iris was used for fusion. Here algorithm was tested under visible wavelengths and in changing lighting environments. Sclera template was generated by using local binary patterns for cancelable identity verification in [17]. UBIRIS V1 database used for verification. The hamming distance was used for testing the algorithm. S. P. Tankasala, P. Doynov, R. R. Derakhshani, A. Ross, and S. Crihalmeanu calculated grey level co-occurrence matrix (GLCM) from conjunctival vasculature. They performed a fusion of LDA and neural network match scores for classification purpose. Experimentation proved that fusion improves classification accuracy [22].

A binary blood vessels skeleton map was developed by using Gabor filters along with a line descriptor [24]. M. H. Khosravi and R. Safabakhsh able to segment sclera by using time adaptive active contour-based method [25]. The same Authors explained A TASOM (Time Adaptive Self-Organizing Map)-based active contour method in [26]. New proposed method of a weighted fusion of conjunctiva and iris was discussed in [27]. Algorithm makes use of the sum rule for fusion A deep learning method based on eye modality was developed in [29]. Max convolution and residual network (MiCoReNet) was used for the improvement in the accuracy. A human identification system based iris and corneal features were explained in the work [28].

Zernike polynomial was used as a feature. Mrunal Pathak, N. Srinivasu, and Bairagi extracted brightness, color, and texture features from the preprocessed eye image. Entropy was calculated from contour-based features. A convolutional neural network (CNN) is employed for sclera, iris, and pupil separation [30]. The fusion of iris and sclera based on Laplace transform was done in [31]. The least mean squared method was used for matching of feature vectors. An algorithm using entropy as a parameter for matching is used in [32]. A convolution neural network (E-CNN) is utilized for the segmentation scheme. Less than 0.9 seconds required for segmentation. Iris and sclera were used to develop a dual authentication system for degraded noisy images [33]. Multimodality of iris, sclera, and pupil was used for the development of the biometric system [34].

Log Gabor features, Y-shaped features, and color histogram features were used as feature vectors for performing fusion. Off angle, iris segmentation is improved by using inner and outer boundaries iteratively. Segmentation accuracy improved up to 99.83% [35]. Work done in [36] used corneal reflection features for off-angle iris recognition. Multiclass SVM was used for classification. J. Daugman in [37] explained iris localization of iris on an eye image. Direct attacks on iris recognition were discussed in [38]. Mainly discussion was done with respect to printed iris and with contact lens variation. The recent development in the field of anti-spoofing is discussed in [39]. This gives the road map to researchers to work it the liveness detection area.

Richa Gupta and Priti Sahgal reviewed the possibility of different attacks at different levels [40] A. Khotanzad and Y. H. Hong explains the use of Zernike moments [18]. They also highlighted the properties of Zernike in terms of rotation and scale variance. The use of DCT for pattern recognition is explained in [19]. In [20] an EER estimation method was used to estimate real and fake speaker models from the client speakers. The importance of Area under the curve (AUC) and its dependence on the distribution among different classes were highlighted in [23].

3.METHODOLOGY

We are proposing a new method of fusion of discrete cosine transform (DCT) and Zernike moment-based features for liveness detection. Transform coefficients act as a new frame for feature extraction where the capturing of minutiae patterns is difficult. In situations such as surgical operations, it is difficult to capture minutiae. Also, transform-based analysis can be an effective solution in the case of the red-eye effect. We have used discrete cosine transform for feature extraction along with Zernike moments. The white portion of the eye which is a significant portion of off-angle eye image mainly consists of low-frequency features and blood vessel pattern consider being a high-frequency pattern. Equation (1) and equation (2) is used to calculate discrete Cosine Transform from conjunctival vasculature image. DCT transform is calculated by using basis function expressed in equation (1). DCT transform is applied on horizontal pixels of conjunctiva and then DCT is applied vertically on exultant horizontal vector.

$$P_k = \frac{2}{N} h(k) \sum_{n=0}^{N-1} x_n \cos\left(\frac{2n+1}{2N} \pi k\right), 0 \le k \le N-1 \quad (1)$$

Where

$$x_n = \sum_{k=0}^{N-1} h(k) P_k \cos\left(\frac{2n+1}{2N} \pi k\right), 0 \le n \le N-1 \quad (2)$$

Equation (3) defines h (k)

$$h(k) = \sqrt{2}, k = 0 \text{ and } h(k) = 1, 1 \le k \le N-1 \quad (3)$$

We have used Zernike moments for feature extraction. Zernike moments calculated by using Zernike polynomials which are orthogonal to the unit circle are expressed by equation (4).

$$x^2 + y^2 \le 1 \quad (4)$$

Zernike moment of order p with q iterations continuous function f(x, y) is defined by equation (5)

Function f(x, y) is defined by equation (5)

$$(Z_{pq}) = \frac{p+q}{\pi} \iint f(x,y) V^*(x,y) dy\, dx,\ x^2 + y^2 \le 1 \quad (5)$$

Where V* is the complex conjugate. The Zernike basis function order p with q iterations is defined by Vpq(y,x). Equation 6 defines the Zernike basis function as

$$(V_{pq})(x,y) = (V_{pq})(\rho,\Theta) = (R_{PQ})(\rho).\exp(jq\Theta) \quad (6)$$

Where p is zero or a positive integer, p-|q| is odd and |q| < p. For (n-m) even, R_{PQ} is defined as equation (7)

$$R_{PQ} = \sum_{l=0}^{l=(n-m)/2} \frac{-1^l (n-l)!}{l! \left[\frac{1}{2}(n+m)-l\right]! \left[\frac{1}{2}(n-m)-l\right]!} \rho^{n-2l} \quad (7)$$

For odd value of (n-m), R_{PQ} is zero.

If f(x, y) is a digital image, Equation (8) shows the Zernike moment can be approximate as

$$(Z_{pq}) = \frac{p+1}{\pi} \sum_{\pi} \sum_{\pi} f(x,y).V_q^*(x,y) \quad (8)$$

The general process of liveness detection based on off-angle iris image can be summarized as shown in Fig.1.

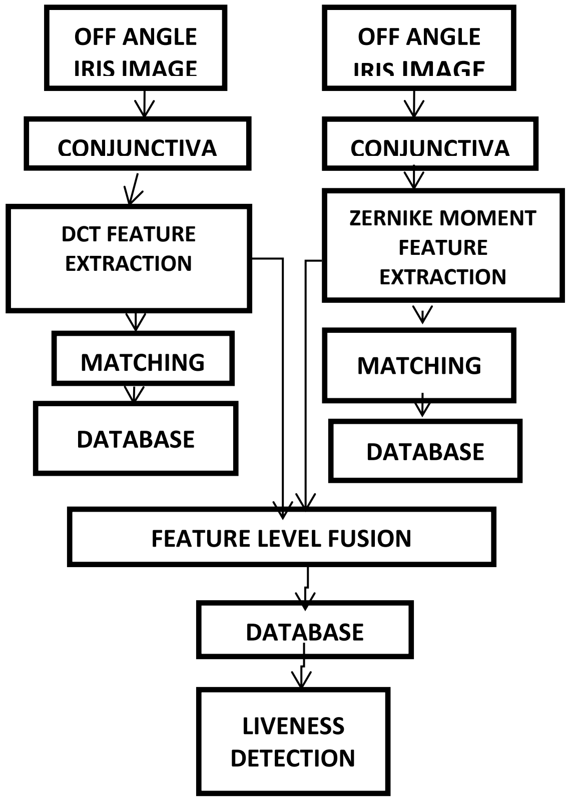

Figure 1. Liveness detection process based on off angle iris eye

The Proposed liveness detection system can be explained by using the following steps

Off-angle iris eye image database generation

We have used a CMITech iris scanner which is is a binoculars-type iris biometrics imaging device. The captured images have a pixel resolution of 640 x 480 pixels with an optical path distance of 350 to 380 mm. Fig.2 shows a picture of the iris scanner.

Figure 2. Cmitech Iris Scanner

Extraction of conjunctiva from an entire eye

We have used the same algorithm defined in [12] for extraction of conjunctiva from an eye image. We can summarize the following steps are used for extracting conjunctiva.

Capture eye image is an RGB image. We use image linearization as the preprocessing step to convert it into a grey image We have generated a binary mask by using the connected component labeling method to extract the maximum white portion from binary image. We have used the standard method used in image analysis to extract white and black portions.

By applying the above mask on the actual image we can get conjunctiva.

In order to have the same size for the image template for further analysis we are finding maximum square and then resizing it to 100 by 100 image for experimentation. Fig.3, 4, 5 and 6 shows a pictorial presentation of conjunctiva extraction.

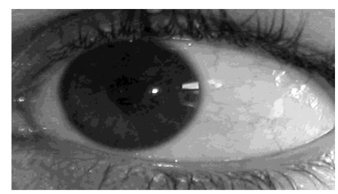

Figure 3. Original off angle Eye Image

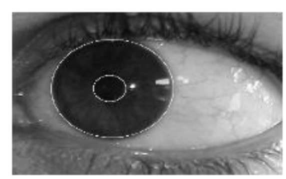

Figure 4. Drawing Concentric Circles for preprocessing

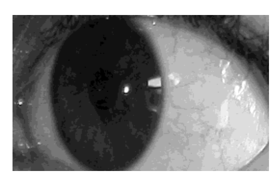

Figure 5. Removsl of Eye lashes from Eye Image

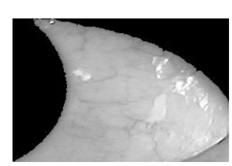

Figure 6. Extraction of Conjunctiva

Matching

Generally, for liveness detection, we can use a support vector machine (Binary SVM) but we are using the extreme learning machine (ELM) due to the advantages explained in section 4. Features extracted from real and fake iris images are compared and liveness score is evaluated.

4. PROPOSED ALGORITHM

Algorithm provides future level fusion analysis of DCT and Zernike moments for liveness detection. Equal error rate plays important role in the robustness of the liveness detection system. The lesser the value of equal error rate better is the performance of the system. The algorithm for feature extraction can be summarized as follows.

We have used an enhanced version of the off-angle iris database used in [12]. It consists of a total of 800 images with 650 real images and the remaining are fake images. Conjunctival vasculature is extracted by using the same algorithm as explained in [12]. Fig. 2.indicates a sample of the database of real off-angle eye images. Fig. 3 and 4 show preprocessing stages for extracting of conjunctiva after preprocessing. Fig. 5 and 6 shows an extracted conjunctiva.

Apply discrete cosine transform and calculate statistical features from it. We have used mean, standard deviation, median, and variance as a feature vector.

Calculate Zernike moments separately on the extracted region of interest. We have used order 2 for moment calculations. Calculate statistical features from moments.

Use extreme learning machine classifier is used to calculate accuracy. We have used the same algorithm as explained in [23].

Liveness detection accuracy is tested obtained by calculating Equal Error Rate (EER) from receiver operating characteristics.

Calculate Area under Curve (AUC).

The feature vector was derived from statistical features defined in step (*b*).

After performing individual testing, we fused features of DCT and Zernike moment by selecting maximum values for statistical features. We adapted the same steps (*e*) and (*f*) for algorithm testing.

Performance of the system is calculated in the form of equal error rate (EER) and area under the curve (AUC) from receiver operating characteristics. Lower the value of EER system performance is better.

Equation (9) is used to calculate Mean (μ).

$$\mu = \frac{1}{M*N}\sum_{x=1}^{M}\sum_{y=1}^{N} F(x,y) \quad (9)$$

Where M*N is the size of an image F(x,y)

Equation (10) is used to calculate standard deviation (std)

$$std = \frac{1}{M*N}\sqrt{\sum_{x=1}^{M}\sum_{y=1}^{N}(F(x,y)-\mu)^2} \quad (10)$$

Equations (11) and (12) are used to evaluate Variance (Var) and Median (med) respectively.

$$Var=(std)^2 \quad (11)$$

$$Med= \sum(F(x,y)-\mu) \quad (12)$$

We have used extreme learning machine for algorithm testing [23]. ELM is the learning algorithm developed for single hidden layer feed forward neural network (SLFN). This method randomly selects the input weights and analytically determines the output weights for the neural network. Speed of operation is also faster than other methods as explained in the literature.

5. EXPERIMENTAL RESULTS

Experiments performed on an extended database used in [12]. We have used the same preprocessing algorithm as in [12] to extract conjunctival vasculature which is used for further analysis. Matlab 2019 software platform is used for experimentation. We have used processor of 1.8 GHz for experimentation. Table I indicate accuracy based on DCT transform coefficients.

Similar experimentation is performed by using Zernike moments. Table II represents the performance of the system based on Zernike moments. Fig.7 shows the comparative analysis of DCT and Zernike moments-based features. It is found that Zernike performs better over DCT for most of the features. DCT performs well in the low-frequency image area. Zernike moments provide rotation invariance. Our region of interest is the low-frequency portion of the eye image. To increase accuracy and to reduce effect flashing at the time of data generation we will adopt a fusion of DCT and Zernike moments.

TABLE I. ACCURACY OF DCT TRANSFORM

Features	***% ge Accuracy***
Mean	90.00
Std	87.13
Var	90.01
Med	83.59
Mean+var	93.88

Features	***% ge Accuracy***
Mean+std	93.88
Var+med	86.65
Mean+std+var	93.88
Std+var+med	86.23
Mean+var+med	94.02
ALL	94.02

TABLE II. ACCURACY OF ZERNIKE MOMENTS

Features	***% ge Accuracy***
Mean	93.05
Std	92.45
Var	93.04
Med	93.19
Mean+var	93.05
Mean+std	93.19
Var+med	92.63
Mean+std+var	93.19
Std+var+med	92.48
Mean+var+med	93.04
ALL	93.32

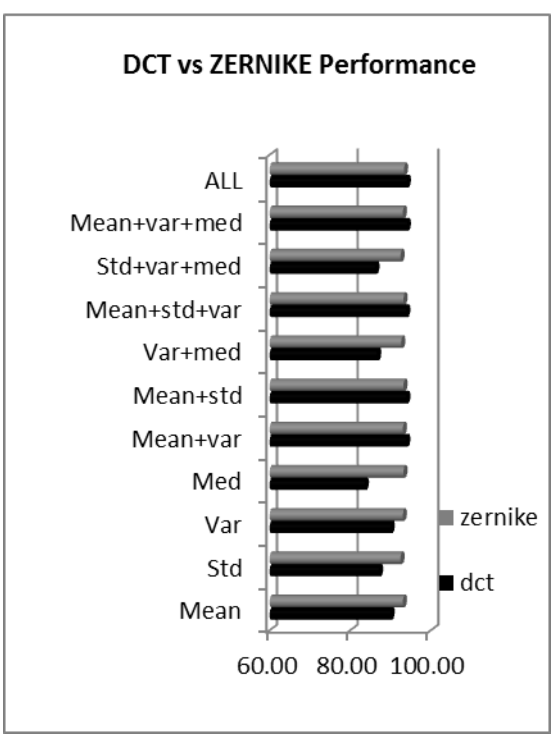

Figure 7. Comparative Analaysis of DCT and Zernike moments

To select optimum features we have found out EER individually for all features. Fig.8 shows variation of EER with respect to all features foe DCT transform.

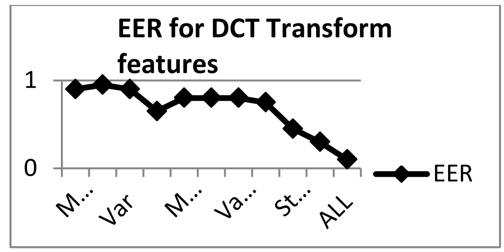

Figure 8. EER Analysis for DCT Features

We performed the same analysis based on Zernike moments. Fig.9 indicates EER based on Zernike moments.

For applications like liveness detection, EER rate plays an important role. Lower the value of EER, the system performs better against fraud users. Figure 8 and Figure 9 show that if we use a combination of mean, standard deviation, variance and, median, the algorithm performs better. As EER is the least with the combination of all four features we consider all four features for fusion All four features based on DCT and Zernike are Concatenated. Table III represents the performance of the system in presence of fusion of DCT and Zernike moments features. Table III clearly shows EER is the same for both methods when we perform experiments by using individual methods. As we fused features from both the methods then EER reduced from 0.1 to 0.08, statistically.

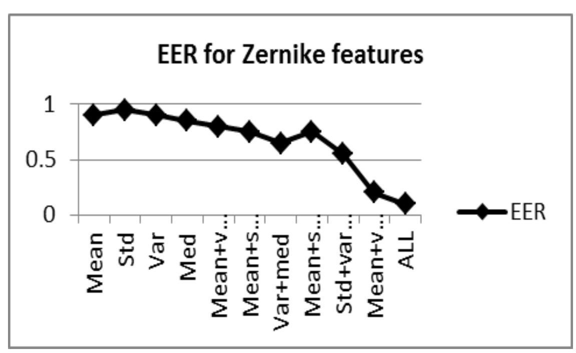

Figure 9. EERAnalysis for Zernike Features

TABLE III. Accuracy of ZERNIKE MOMENTS

ethod	***AUC***	***EER***
DCT Transform	94.02	0.1
Zernike Moments	93.32	0.1
DCT+Zernike Fusion	94.16	0.08

Fig.10 shows that if we use a fusion-based approach then EER; it reduces by 20% over both DCT and Zernike-based approaches respectively,

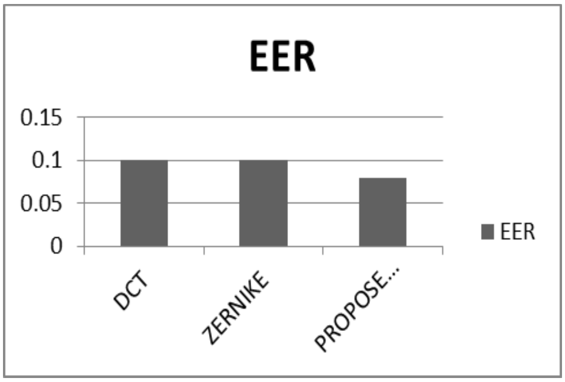

Figure 10. EER Analysis for Zernike Features

The total area of a region of interest (ROI) is divided into four equal portions A, B, C and D respectively as shown in fig.11. We performed DCT and Zernike moments based algorithms on all four areas individually

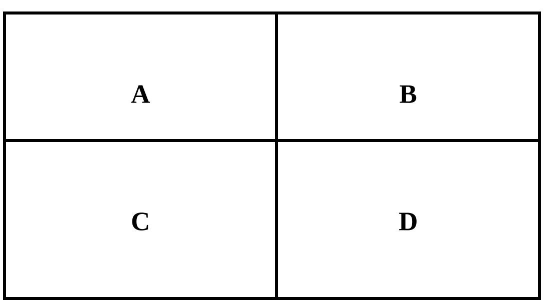

Figure 11. ROI Equal Division

We have calculated equal error rates for all regions A, B, C, and D respectively. Table IV shows performance based on DCT features.

TABLE IV. Accuracy for Divided Regions based on DCT

Region	*AUC*	*EER*
A	94.02	0.1
B	94.00	0.1
C	94.01	0.1
D	94.03	0.1

It can be shown there is a negligible effect of the division of ROI for the DCT algorithm. We also did Zernike moment experimentation on similar areas. Table V shows performance based on Zernike moments. It proves that there is no such significant area in ROI htat has maximum effect on the performance. So fusion-based approach can be adapted to entire ROI. Analysis shows clearly that we require maximum ROI for increasing system accuracy.

TABLE V. Accuracyfor Divided Regions based on Zernike

Region	*AUC*	*EER*
A	93.00	0.1
B	93.01	0.1
C	93.00	0.1
D	93.01	0.1

6. CONCLUSION

Paper provides a novel approach of Fusion based on DCT and Zernike moments for liveness detection. The discussion shows performance parameters AUC and EER improved due to fusion. The methodology also shows the importance of conjunctival vasculature as a new upcoming biometric modality. Effect of flashing of light at the time of database generation is nullified due to use of Zernike moments. DCT works efficiently on conjunctival vasculature due to in low frequency region. Off angle iris captures maximum portion of conjunctiva, leads ideal combination with iris for applications in biometric field. In future research should focus on the direction of using multi-directional transforms to reduce EER. Attention is also provided towards reducing preprocessing time for increasing the efficiency of the system

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