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Abstract This work proposes a sclera vessel texture pattern synthesis technique. As it is difficult to produce a a large-scale collection of real sclera data, synthetic data can be a useful alternative for researchers. Sclera texture was synthesized by a non-parametric based texture regeneration technique. A small number of classes from the UBIRIS version: 1 dataset was employed as primitive images. An appreciable result was achieved which demonstrates the successful synthesis of sclera texture patterns.

1 Introduction

Sclera is the white region containing blood vessel patterns around the eyeball. Recently, as with other ocular biometric traits, sclera biometrics has increased in popularity [1-11]. Some recent investigations performed on multi-modal eye recognition (using iris and sclera) show that iris information fusion with sclera can enhance the applicability of iris biometrics in off-angle or off-axis eye gaze. To establish this concept, it is first necessary to assess the biometric usefulness of the sclera trait independently.

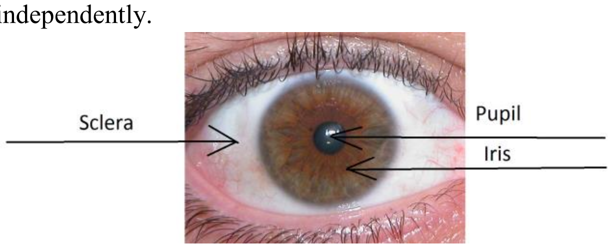


Fig. 1. Colour image of an eye consisting of a pupil, iris and sclera area.

Moreover the research conducted on this subject is very limited and has not been extensively studied across a large population. Therefore, to-date the literature related to sclera biometrics is still in its infancy and little is known in regard to its usefulness in personal identity establishment for large populations. It can be inferred from recent developments in the literature that a number of independent research efforts have explored the sclera biometric and serval datasets have been proposed, which are either publicly available or are proprietary datasets. Efforts were also made to address the various challenges which reside in processing the sclera trait towards personal identity establishment. It can be noted from the literature that the datasets developed are with a limited population of a maximum of 241 individuals. Growing the population is a difficult task and moreover it also depends on the availability of volunteers. On some occasions, they may be available for a particular session and may not be available in the next session, which again can bring inconsistency to the dataset. These types of instances can be found in the datasets proposed in the literature. Hence establishing this trait for a larger population and generating a larger representative dataset is an open research problem.

In the biometric literature for larger population data collection, data synthesis is a proposed solution. Data synthesis refers to the artificial regeneration of traits by means of some computer vision or pattern synthesis-based regeneration techniques. Several such techniques have been proposed in the literature for iris biometrics [14] (texture pattern on the eye ball employed for biometrics as shown in Fig 1.). In order to mitigate the above-mentioned problem in sclera biometrics, similar to the iris biometric, we propose a sclera biometric synthesis technique. The sclera contains the white area of the eye along with vessel patterns that appear as a texture pattern. Therefore we have applied texture regeneration theory for this application.

The organization of the rest of the paper is as follows: The concept of our proposed method is presented in section 2. In section 3 our experimental results along with the dataset are described, as well as a preliminary discussion on our experiments. Conclusions and future scope are presented in Section 4.

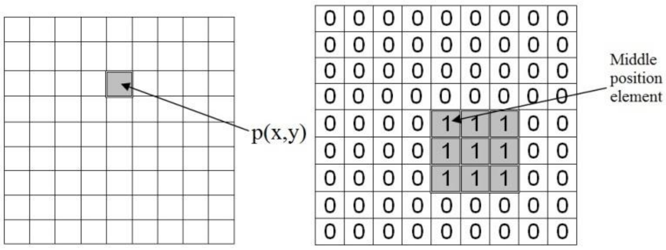
2 Proposed technique

Non-parametric Texture Synthesis using Efros & Leung's algorithm [13] is applied in this work as a remarkably simple approach. First, initialize a synthesized texture with a 3x3 pixel "seed" from the source texture. For every unfilled pixel which borders some filled pixels, find a set of patches in the source image that most resemble the unfilled pixel's filled neighbors. Choose one of those patches at random and assign a color value to the unfilled pixel from the center of the chosen patch, and repeat until the texture is achieved.

The detailed steps of our implementation for this method are as follows:

Step 1: Take a Primitive Image (PI)/the original image from which the image will be synthesized.
Step 2: A pixel is chosen randomly from PI. Let the pixel be p(x, y) as shown in (Fig. 2a).

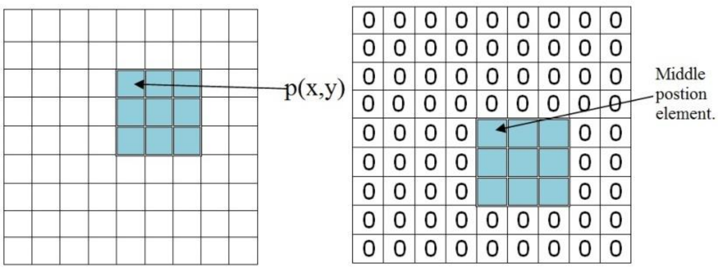
Step 3: A matrix (SI), having dimensions the same as PI is created and initialized with zeros.
Step 4: Seed Size=3.
Step 5:A 3x3 block (as seed size=3) is chosen from SI in such a way that its top left



(a) (b)

Fig.2. (a) Primitive Image (PI). (b) SI Matrix.

most element's position is the middle element's position of SI (as described in Figure 2b).
Step 6: Similarly in Figure 3a. a 3x3 block is selected from PI in such a way that its top left most pixel is p(x, y) which was obtained in Step 3.
Step 7: The 3x3 block of SI is replaced by the 3x3 block of PI (Figure 3b).



(a) (b)

Fig. 3.(a) 3x3 block is selected from Primitive Image (PI), (b) SI Matrix with a replaced 3x3 block from PI

Step 8: Another matrix (SI-1) is created with the same dimensions as SI and all its elements are initialized with zeros.
Step 9: A 3x3 block is obtained from (SI-1) by using the same method described in step 6, and the block is initialized with ones (Figure 4a).
Step 10: Another matrix SI-2 is formed by dilating SI-1 by 1 pixel. So the neighbors of the block are assigned with ones (Figure 4b).
Step 11: A column-wise neighborhood operation is performed on SI-2 as follows:
By sliding a 3x3 window over every element of SI-2 and the corresponding element is replaced by the value obtained by summing all the elements residing in the window (Figure 5).
Step 12: The positions of neighbor elements are listed after taking their values in descending order (Figure 6).

Step 13: Elements of SI having the same position as that obtained from Step 12 are considered.
Step 14: A window (we consider here the window size is 3x3, but in our experiments we consider it as 39x39) is placed on every considered element in such a way that the elements should be the middle element of the window (Figure 7).
Step 15: After placing the window on every element of SI, the elements within the window are matched position-wise with the corresponding elements of PI, and an element is randomly chosen where the Match Error < Max Match Error threshold. We considered 0.1 as the value of Max Error Threshold.

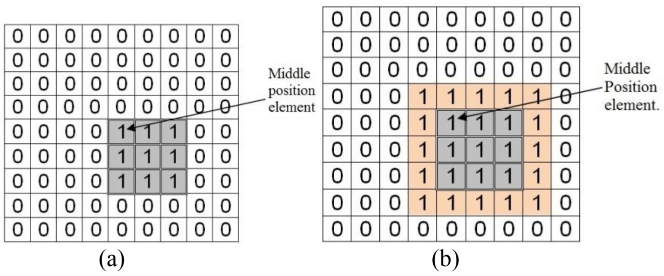


Fig. 4. (a) SI-1 Matrix**. (b)** SI-2 Matrix.

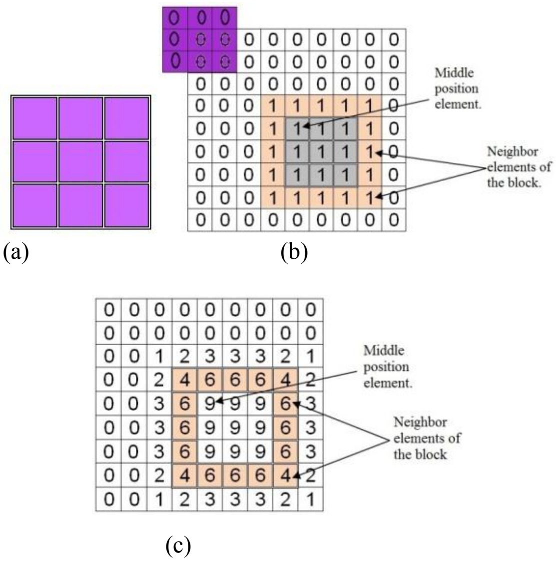


Fig.5. (a):3x3 Window, (b):Column-wise neighborhood operation on SI -2 matrix with window, (c):SI -2 matrix after column-wise neighborhood operation.

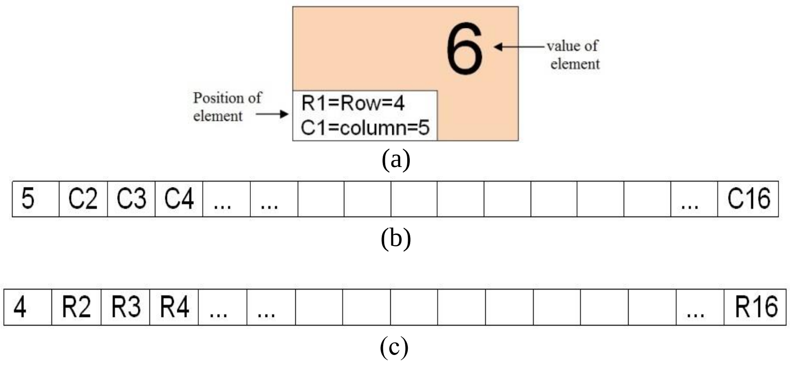


Fig.6. (a)**:** A neighbor element of an SI-2 matrix along with its row/column position, (b), (c): Respective row, column position list of neighboring elements in the SI-2 matrix.

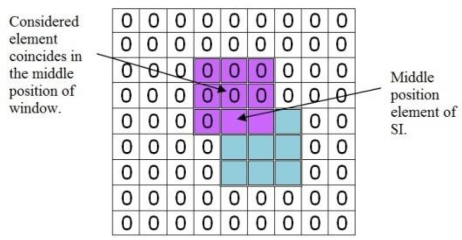


Fig. 7.SI matrix with middle pixel matched

Step 16: Let element q(x1, y1) of the SI be an element that satisfies Step 15, then we assign,

SI(R, C) =PI(x2, y2),

Where, x2=(x1+(window size/2)) and

y2= (y1+ (window size/2))

Step 17: SI-1(R, C) =1.

Step 18: Step 13 to Step 17 are iterated until all the elements of SI have the same position obtained from Step 11.

Step 19: Step10 to Step 18 are performed until all elements of SI -1 are assigned with 1.

Step 20: Finally we obtain the SI as the synthesised image of PI.

3 Experimental details

Details about the implementation and the setup of the experiments are discussed here, prior to presenting the detailed results.

3.1. Dataset

In order to evaluate the performance of the proposed method, the UBIRIS version 1 database [12] was utilized in these experiments. This database consists of 1877 RGB images taken in two distinct sessions (1205 images in session 1 and 672 images in session 2), from 241 identities and images are represented in the RGB color space. The database contains blurred images and images with blinking eyes. Both high resolution images (800 × 600) and low resolution images (200 × 150) are provided in the database. All the images are in JPEG format. A few examples from session 1 are given below in Figure 8.

(a) (b) (c)

Fig 8: Different quality eye images of Session 1 from UBIRIS version 1.

For our experiments, the first 10 identities from session 1 were reconsidered. 5 samples from each identity were selected and their sclera vessel patterns were manually cropped as shown below in Figure 9. For each real image, a synthesized image was generated. The synthesised images generated from the corresponding images in Fig 9 as primitive images are shown in Figure 10.

(a) (b) (c)

Fig 9: Manually cropped vessel patterns from eye images of session 1 UBIRIS version 1.

(a) (b) (c)

Fig 10: Synthetic sclera vessel patternsfrom eye images of session 1 from UBIRIS version 1.

3.2. Experimental setup

In order to establish the usefulness of the synthesized sclera vein patterns as a biometric trait, we observed the outcomes of some experiments. We undertook to determine the accuracy of the trait as a biometric trait. In order to feature the vein pattern and classification, the feature extraction and classification technique proposed in [5] were employed. We performed two sets of imposter and genuine experiments. In the first set we trained the system with 3 primitive images and tested it with the rest of the 2 primitive images. Maintaining the same protocol, the experiments for synthetic images were performed. In another set of experiments, the system was trained with 5 synthetic images and tested with 5 primitive images and vise-versa.

For the first set of experiments, scores 10*2 for FRR and 10*9*2 scores for FAR statistics were obtained, whereby10*5 scores for FRR and 10*9*5 scores for FAR statistics were obtained for the second set of experiments.

3.3. Results

The results of the experiments performed are described in this subsection in Table 1.

Table 1. The results of the experiments performed

Train set	Test set	Identification Accuracy in %	Verification Accuracy in %
Primitive Image	Primitive Image	100	100
Synthetic image	Synthetic image	100	100
Primitive Image	Synthetic image	31	90
Synthetic image	Primitive Image	48	75

The first set of experiments i.e. with the primitive image (as training and test sets) or synthetic image (as training and test sets) were performed to establish the usefulness of the synthetically-generated patterns as a biometric trait. The second set of experiments was performed to find the inter-class variance in between each class of synthetic images. In both the scenarios, the desired result is achieved which can be depicted from the above table and the ROC curve in Figure 11.

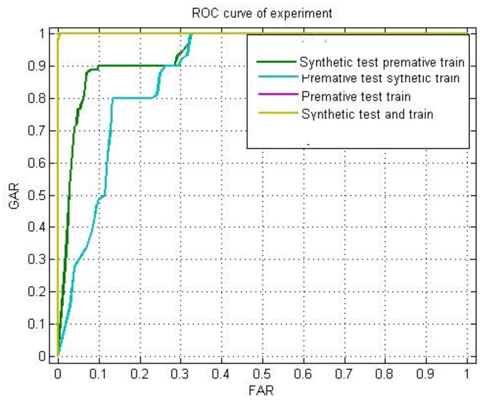


Fig 11: ROC curve of the experiments

3.4. Discussion

This work is an initial investigationon into sclera pattern synthesis. Here, the images from the original (or the primitive) version are cropped manually and used for sclera vessel pattern synthesis. Although satisfactory results were achieved in the proposed experimental setup, the time complexity of the implementation is found to be high. The experiments were performed on a cluster server machine in a Linux environment using Matlab 2015. Therefore it can be easily assumed that it will take more time to generate the total vessel patterns of the eye. Future efforts to minimize this time will be an open research area for this field.

4 Conclusions and future scope

In this work we proposed a non-parametric texture synthesis method to generate synthetic sclera vessel patterns. We employed a set of images from the UBIRIS version 1 dataset as primitive images. Appreciable results were achieved in the experiments, which indicates satisfactory synthesis using the method.

Future scope of our work will concentrate on the synthesis of the sclera vessel patterns without a manual cropping technique to generate the primitive images and to reduce the time complexity of the implementation.

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