Sclera Segmentation techniques

Swechchha Sharma, Gokul Rajan V

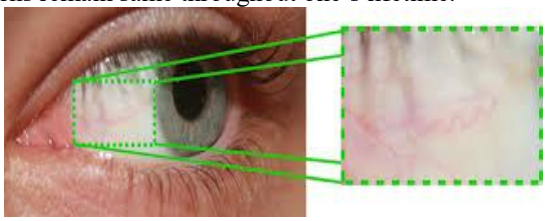
Abstract*: Biometric Recognition is process which plays a vital role in many fields like security, authenticity, identification. The term biometric is the biological parts of humans which have a unique feature to isolate the individuals. Iris, fingerprint, palm, vascular pattern, voice, signature, face, DNA are the biometrics which are available in the world. Still there are few more biometric exist with unique feature like sclera, the white area of an eye. Blood vessels in sclera area have the unique pattern for every individual. In order to recognize the individuals features if sclera has also used but still how to isolate the feature from the eye image is a question mark. The challenge is the sclera has been surrounded by iris, eyelid and eyelash. Many procedures and methods has been introduced to segment the sclera form the eye but still the efficiency of the approaches has to be evaluated because segmentation accuracy will affect the recognition accuracy. The comparison has been tabulated and the analysis results are briefed in the result.

***Keywords*: Digital Image Processing, sclera Recognition, biometrics, feature extraction, Sclera segmentation.**

I. INTRODUCTION

A. Overall Description

Sclera Segmentation is a form of biometric technique. This can be used for the recognition of an individual, who owns the particular data or who is allowed to access it. Sclera is, basically, the white portion of the eye, consisting of four tissues i.e., episclera, stroma, lamina fusca and endothelium. The sclera has the randomly distributed veins on it, as shown in fig.1[21] The shape of the sclera, including the pattern on it, helps in the process of recognition. We should know that this is a unique feature of a human being, which cannot be spoofed, lost, stolen or forgotten. Also, it is never same, even in twins. Additionally, our both eyes may have the same shape but the vessel pattern always differ from each other. Thus, they can be perfect for the personal identification, as the patterns remain same throughout one's lifetime.



(Fig.1 Sclera including vascular pattern)[1]

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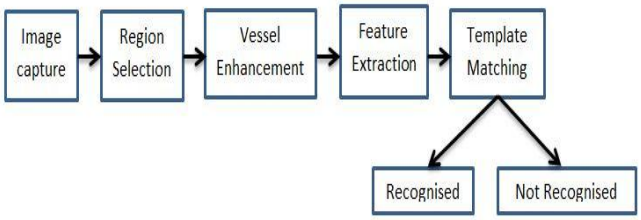
The recognition system has a procedure for the working of the system, which is explained in the fig 2. According to the figure, we can see that the image is first captured in the system, and then the sclera region, excluding iris, eyelid and eyelashes, is identified for the further process. After that, the vessels in the sclera region are enhanced, as they are very minute, and then the features are extracted. After the extraction, the matching of features is performed, which gives the result, whether the pattern is recognised or not.



(Fig.2 The process of sclera recognition system)[2]

B. Motivation

The motivation for the sclera recognition system, in spite of having other techniques for biometrics, comes from the accuracy it gives to the system. We have many other kinds of recognition techniques, such as, fingerprint, face recognition, voice recognition, retina matching, iris recognition, etc. still sclera recognition can be better than other techniques, because:

1) It has the highest accuracy among the other biometric techniques.
2) These sclera vascular patterns have high amount of randomness.
3) There is no effect of age on it, as the vascular pattern remains the same, throughout the lifetime, once it has been developed properly.
4) It can be captured in visible light condition, rather than Infrared light condition, which might damage the eye-cells due to its close contact.
5) It cannot be spoofed, as it is the eye-print, like a fingerprint, which is unique for every individual.
6) As sclera doesn't depend upon the power of the eye, therefore it can be used for the person without eyesight.

C. Purpose

The purpose of this paper is to figure out what is going on in the industry, in terms of sclera segmentation and what are the challenges that are or could be faced in the development or working phase of this biometric technique.

For the process of sclera segmentation, many techniques were practiced and the main research challenges faced were as follows:

a. *Target Area*: The region of sclera might not be exposed completely during the image capturing phase, due to the movement of eyelids.
b. *Computational cost:* The computational cost is high for the recognition procedure.

So, as we know that sclera recognition is an emerging technique, we must know about some of its basic development and research till date. Therefore we are going to discuss about some techniques and the challenges faced during the execution.

II. LITERATURE SURVEY

Sclera Recognition is basically a two-step procedure in most of the cases, as discussed in previous papers. The first step considers the region selection, while the other stage is for performing feature extraction. But, this classification might differ in different methods.

According to [2], the first step is mask generation, where we generate two masks. For the first mask, we apply RGB & OSTU method and later on, use erosion filter. Then for the second mask, we need to apply binary operations and a local OSTU method, after that the image contours are extracted and analysed. Now, the second step in this method is vessel extraction, which is done by extracting green channels of sclera image and then applying LAHE to the sclera region[4]. Later on, a series of Gabor filter is applied for enhancing vascular pattern and it is ready for the template matching.

Then there is a two-step approach, that has been proposed [7],

1. Periocular Region Detection
2. Sclera Segmentation (3-approaches)

a. FCN (Fully Convolutional Network): Here, using CNN, the features are extracted, then those features are passed through convolutional layer, generating an output, then that output is processed by FCN8 architecture.

b. ED (Encoder Decoder): It is used, basically for the dimensionality reduction and file compression. Here, for every encoder there is a stack of decoder which feed a soft-max classification, by mapping low resolution features extracted by the encoder.

c. GAN (Generative Adaptive Network): It is composed of generator and discriminator networks, where generator takes noise as input and produces more realistic samples, whereas the discriminator receives those samples of training data and distinguishes them into real & synthetic data.

Next we have a pupil's centre locating method [6]. It is also divided into two stages. First one is pre-processing stage, here the system locates the centre and determines the circumference, then scales down the image and set the iris radius to 18 to 28 pixels, which decreases the time complexity and increases the accuracy. Then the second is Training and Classification stage by SVM. Now after the image enhancement, feature extraction is performed by SIFT based skills. After that, the bag-of-features method is applied and the main features are fed into the SVM for the training of the classifiers [5]. Here, it is observed that, if the suggested number of categories is larger, the recognition accuracy would be better.

Now we have a method [8] that doesn't require the pre-processing stage. It is a deep learning based method (Sclera network i.e. Sclera-Net), which detects the boundaries of the sclera and acquire the class (sclera class and non-sclera class) pixels. Sclera-Net consists of convolutional encoder and decoder network, based on residual connections (Residual Building Block i.e. RBB). The encoder has seven RBB (3 NIM & 4 IM). It compresses the image and gives the descriptive representation of the image as output, which is the input to the decoder. The decoder also has 7 RBB, as it converts the image back to the original dimensions. It does the process of up-sampling, using max pooling indices. It has various layers including soft-max layer, which uses soft-max function for the estimation of the class, and pixel classification layer, just after the soft-max layer, which uses cross entropy loss function to predict the pixel label from the input eye image. After passing the image through the above process, a mask is obtained, consisting of different values, based on classes.

III. REVIEW ON METHODOLOGIES USED PREVIOUSLY

Till now, many techniques are proposed to capture the sclera image and also for extracting its features. Some of them will be studied as follows; all the methods which were proposed came into existence, due to some drawbacks that were faced during the process.

A. Vessel Extraction Method using Masks

One of the basic drawbacks was the inclusion of eyelid, eyelash and iris in the captured image. So to avoid it, [2] was introduced. It proposed a method of generating masks for image capturing and then vessel extraction is performed using, green channels of sclera image.

As we know the thickness of vessels in each one's eye may vary, therefore to achieve the accuracy, morphological thinning algorithm and binary morphological operations are used to remove the exterior pixels from the detected vascular pattern. Later on a series of 2D Gabor filter is applied for enhancing pattern.

The process of sclera segmentation and vessel extraction using masks includes the following steps:

1) Generate first mask:
   a. First of all, the RGB is applied for classifying each pixel as skin or non-skin area. Then the RGB eye image is converted to YC_RC_B space, which is then extracted to C_R channel image.
   b. Then the OSTU method is applied for getting sclera area, through which the histogram is being generated using K-means.
   c. Lastly, the erosion filters are being used to erode the white pixel inside the iris.

2) Generate second mask:
   a. The Binary operations are applied on the grey image of eyeball to figure out the iris and eyelash area. The formula used for the purpose is as shown below:

$$avg\_value = \frac{\sum_{x,y} F(x,y)}{n} \quad (1)$$

b. Then the Local OSTU method is applied on the basis of statistical values of pixels, except the iris and eyelash area in C_R image.
c. Later on, the eyelid and eyelash are removed by extracting and analysing the image contours.

3) Extract the vascular pattern:

a. The green channels of sclera image are extracted because it has significant contrast between the veins and the background.
b. Then, LAHE (Local Area Histogram Equalizer) is being applied to the sclera region to enhance the green layer of the coloured image. Here, to reduce the calculation part, only the pixels in the sclera region are counted in the histogram.
c. A series of 2D Gabor filter is then applied for enhancing the vascular patterns. The typical Gabor filter applied is as follows[2]:

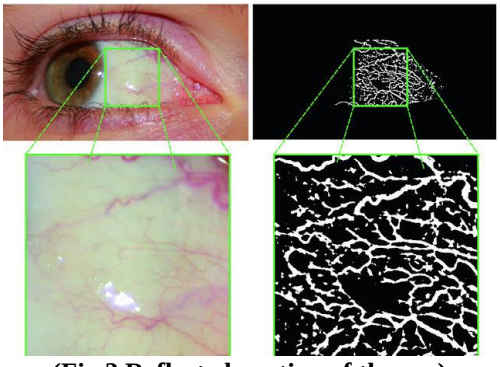
$$\begin{cases} G(x,y,\lambda,\theta,\psi,\sigma,\gamma) = \exp\left(-\frac{x'^2+\gamma^2y^2}{2\sigma^2}\right)\exp\left[i\left(2\pi\frac{x'}{\lambda}+\psi\right)\right] \\ x' = x\cos\theta + y\sin\theta \\ y' = -x\sin\theta + y\cos\theta \end{cases} \quad (2)$$

d. Now, an adaptive threshold binary method is applied, based on the mean values of the neighbour pixels.

4) Then to achieve the accuracy, the exterior pixels from the detected vascular map are removed be applying morphological thinning algorithm and binary morphological operations. Then, later on the one-pixel skeleton running along the centre of the vessels can be created.

B. FCN and GAN method

As we have seen [9], while capturing of image, there can be a chance of reflection, in the sclera region, therefore that can result to a defect in the final result, as shown in fig.3.



(Fig.3 Reflected portion of the eye)

Hence, we use periocular region detection technique [7] to resolve the issue. In this way, the mirror effect can be minimised, so as to get efficient results.

The Fully Convolutional Network and Generative Adversarial Network approach for sclera segmentation is performed in the following way:

1) Periocular Region Detection
   a. The object detection framework, named as YOLO, is being used, but for lesser computational cost, fast-YOLO was introduced.
b. Fast-YOLO takes PRD network as input, which has the set of already trained images, without the use of pre-processing. Also it takes ROI (Region of Interest) as the coordinates.
c. It returns the object with confidence of 0.25 or higher. If more than one region has been detected and returned, then the highest confidence region is used, but if no region has been detected, then the next step is executed with the original image.

2) Sclera Recognition

a. The FCN is applied by extracting the features, using CNN. Then those extracted features are passed through (1×1) convolutional layer, which generates an output of (10×8×6).
b. Now the encoder-decoder is used for dimensionality reduction and file compression. Here the Decoder puts the low resolution features, which are extracted by the Encoder, to the image with same dimension as input.
c. Then the GAN is being applied, which is based on deep neural network. It takes noise as input then generates samples and receives samples of training data. This produces more realistic samples and distinguishes real and synthetic data.

C. SIFT Features and SVM Learning Based Sclera Recognition

Nowadays, while capturing any image, we face a common issue, i.e. noise disturbance. So to avoid this, a method was proposed, which is based on [6]. Here, first of all the sclera masks are obtained, then the sclera vessels are enhanced, and after that, the vascular pattern is more visible and also the image with noise effect can restore its real details. Using this technology, the sclera vessel features are extracted after the image enhancement with the help of bag-of-features methodology. It uses K-means scheme for the generation of histogram and SVM scheme for the identity classifier, after training. Hence the process reduces the noise impact and gives more accuracy.

The procedure of SIFT features and SVM learning based sclera recognition method is divided into two major stages:

1) Pre-processing stage:

a. Here the system locates the pupil's centre coordinate to decrease the calculated amount when the iris recognition is active. This way, it helps to decrease the time complexity and increase the segmentation accuracy.
b. Then the proposed fast method is applied, i.e., first select the region, then scale down the image ratio to $1/100^{th}$. Now detect the circumference sector and set the iris radius (i.e. 18-26 pixels).
c. Sclera mask is then generated, that helps in vessel enhancement through green channel image.
d. After the enhancement, only the vein texture is visible and the noise impact is removed from the image to provide more accuracy.

2) Training/Classification stage (by SVM):

a. The blood vessel features are extracted, using the SIFT based skills.
b. Then the bag-of-features method is applied to put the characteristics of all the training data set into the bag.
c. K-means algorithm is then used to collect the similar features in a bag to form a dictionary, where k represents the word count.

d. Now the dictionary is being referred to get the histogram of main features. Later on those features are fed in the SVM to train the classifier.

Therefore to gain more accuracy, the number of suggested categories must be larger. As the number of categories is directly proportional to the fault tolerance.

D. Sclera-Net Method

So as to get more accurate, a new method of recognition was proposed, based on Sclera-Net (Encoder-Decoder). As the vessels in the sclera region are so defocused and unclear, therefore we need something to make our results more accurate. In this method, the pre-processing is not performed, but the image is directly fetched by the encoder and the tiny features of the image are selected as input, which is then compressed, and the output is send to the decoder. Then the process of up-sampling is performed and the determining of sclera and non-sclera class is performed, in the decoder. This way, we can achieve accuracy and efficiency by the system.

The Sclera-Net method [8], is a deep learning based method which has only one stage that doesn't require any pre-processing, unlike other methods. But it can be divided into encoder and decoder as follows:

1) Encoder:

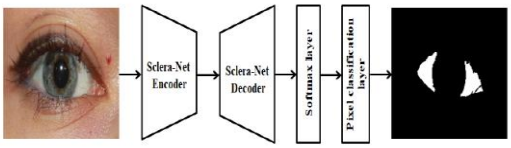
a. It compresses the image and gives the descriptive representation of the image as output, which is later on sent as input to the decoder.

b. It has 7 residual (RBB) connections, with 3 NIM and 4 IM.

2) Decoder:

a. First the up-sampling is performed, using max-pooling indices. Then the detection of sclera and non-sclera class is done, using softmax loss function in the softmax layer.

b. Then the pixel passes to the classification layer, which is present next to the softmax layer. Here the pixel label from the input eye image is predicted, which is performed using cross-entropy loss function.



(Fig.4 Overview of Sclera-Net method)[8]

After passing through the encoder and decoder, a mask is obtained, as shown in Fig.4, It consists of different values which are based on classes (i.e. sclera and non-sclera class). Later on, the template matching is performed.

E. UBIRIS.V1 Database

UBIRIS.v1[10] is the database that has been used with the above methods. It is divided into three categories, good quality images, average quality images and poor quality images. This database consists of 1877 color images, from 241 people, in .jpeg format. Its images includes noise factor, relative to reflections, luminosity and contrast which makes it better from the former databases (CASIA and UPOL). This was captured in two different sessions, in 2004. This file can be downloaded in .zip format, which is also password protected. The camera used for capturing images is Nikon E5700 5 MP which gives the image of size 600 × 800 with 300 dip resolutions and capturing distance of 20 cm.

IV. RESULTS AND DISCUSSIONS

As we are using UBIRIS.v1 database[10] in all of our recognition methods, the end results obtained during the procedure are matched with the actual results, and the accuracy percentage obtained by the systems are mentioned in the Table 1. The methods used in the previous papers are being compared on the basis of their precision, recall and F-score, which can be seen in the Table 2.

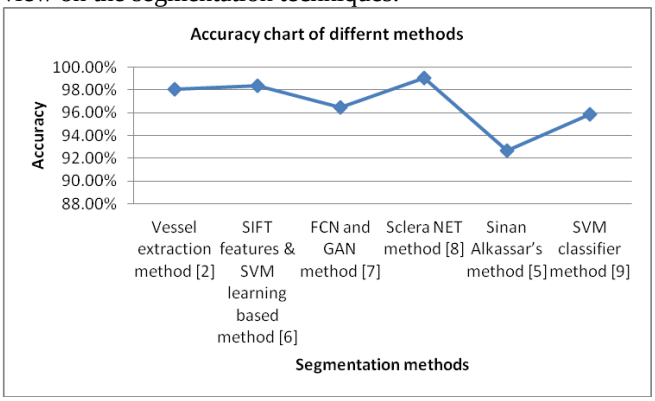
Table I: Accuracy of different methods

Method	Accuracy
Vessel extraction method [2]	98.10%
SIFT features & SVM learning based method [6]	98.35%
FCN and GAN method [7]	96.45%
Sclera NET method [8]	99.07%
Sinan Alkassar's method [5]	92.65%
SVM classifier method [9]	95.85%

*performed using UBIRIS.v1 database

Table I has clearly show the different sclera segmentation and its accuracy. As the different methods secures different accuracy. Since it's a matter of fact to consider the Recall, Precision, F score and computation time taken to make it complete. For the same Table II will witness in detail. The accuracy of the segmentation has been plays important role in recognition result. Because from the segmented portion of biometric the features are extracted for the further process called feature matching and feature registration.

Fig 5 illustreate the compariosn analysis of the different sclera segmentation methods segmentation accuracy. As the segmentation is important step in the recognition system which has high impact over the recognition accuaracy. So it is unavaodable to notice the accuracy of the sclera segmentation. As the importance are notted so the graph has been created to compare the same which shows us a clear view on the segmentation techniques.



(Fig.5 Comparision of different sclera segmentation methods)

In the figure 5 there are 6 different methods compares which are vessel extraction method, SIFT features and SVM learning method, FCN and GAN method, Sclera NET method, Sinan Alkassar's method and SVM classifier method. From the table I it is identified that the NET method of segmentation scores the good accuracy.

Table II: Recall, Precision and F-score obtained during the respective methods

Methods	Recall%	Precision%	F1-score%
Seg-Net	72.48±17.15	87.52±08.53	77.82±13.08
FCN	87.31±06.68	88.45±06.98	87.48±03.90
Sclera-Net	89.18±06.85	92.55±04.87	90.56±03.62
GAN	90.02±05.46	85.96±07.90	87.52±03.74

V. CONCLUSION

Many techniques have been discovered, in these recent years, such as, *Vessel extraction method*, which is performed by generating masks; *SIFT features and SVM learning based method*, which first locates the iris, then performs further processing; *FCN and GAN method*, which removes the error generated by the reflection in the image, then processes the segmentation method; *Sclera-Net method*, it doesn't require multiple step approach, it is performed in a single step. Some of them are good at accuracy, some in security and so on. But after discussing all these different methods in this paper, the Sclera-Net method can be considered as the best method, based on some major criteria, i.e. security, interoperability and accuracy. As compared to other methods, it is more accurate, time saving and cost saving, therefore more efficient than other methods.

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