

An Efficient Segmentation Method Based on Local Entropy Characteristics of Iris Biometrics

Ali Shojaee Bakhtiari, Ali Asghar Beheshti Shirazi, and Amir Sepasi Zahmati

Abstract—An efficient iris segmentation method based on analyzing the local entropy characteristic of the iris image, is proposed in this paper and the strength and weaknesses of the method are analyzed for practical purposes. The method shows special strength in providing designers with an adequate degree of freedom in choosing the proper sections of the iris for their application purposes.

Keywords—Iris segmentation, entropy, biocryptosystem, biometric identification.

I. INTRODUCTION

BY the advance of the concept of the electronic world village into human societies from one side and the increasing need for restricting access to confidential data from the other, the need for introduction of modern and effective authentication schemes are becoming more necessary. In this case biometrics shows a distinct and unique presence. The fact that biometric data are the distinct character of the individual and are seldom or never changed because of external effects, puts biometric in an advantageous position compared with typical nonpersonal schemes based on PIN codes and passwords. Among the present biometric topics human iris has a distinctively promising character. Its special location in the eye structure makes, unlike e.g fingerprints, capturing unwanted copies harder and more complicated, also iris shows distinctive characters related to its shape, form and specially texture and surface features, which in return delivers a high amount of relatively reliable data for according application processing.

Conventional iris based authentication schemes use a double step process for the identification of individuals. In the first step a reference iris image is captured from the owner and after performing image processing algorithms the obtained data is stored in a database. In the 2nd step and during the authentication process a sample image is captured from the claimer, which goes through the same processing algorithms. Afterwards by making comparison between the previously stored data and the present one the validity or invalidity of the claim is deduced and accordingly the former leads to authentication and the later to rejection.

However to store the database of the iris reference images in someplace always results in the threat of the database being hacked and therefore the entire security vanished. The first solution that seems reasonable is to somehow omit the necessity for storing image database and finding another alternative for fulfilling the authentication process. Hao,

Anderson and Daugman [3] have proposed an effective method based on combining cryptography and biometrics for omitting the need for storing the reference data in the system structure. However as it is passively shown in [3] the structure suffers much from the presence of the burst noise which in return asks for sacrificing a part of system capacity for suppressing the unwanted effects of the burst noise. Also from the view of the authors of this paper it may not be a proper idea to choose the entire surface of the iris image for the key strengthening purposes as the presence of high level of correlation in iris data can result in dependent and therefore weak key strings.

The method which is presented in this paper and which shall be called “local entropy method” in the rest of the paper, is primarily designed as an alternative for classical iris segmentation methods like the Hough transform. However, as a secondary application it shall also be shown that the method provides a means for choosing the best regions within the iris, for biocrypto purposes. Moreover, the results of the experiments show that combined with proper image processing methods, the method shows a strong resistance against the effects of burst errors.

The remainder of the paper is organized as follows. After the introduction in section 2 the mathematical background of local entropy method is explained. In section 3 the necessary image processing methods required for preparing the image for local entropy method are described. In section 4 the potential applications of the method are discussed and compared with similar cases. Finally the conclusions are given in section 5.

II. DEFINITION OF LOCAL ENTROPY METHOD

A. What is Local Entropy?

According to Shannon’s 2nd theorem [1] if the event i occurs from a set of valid events, with the probability p_i the amount of uncertainty related to the event is equal to:

$$H_i = -\log_2(p_i)(\text{bits} / \text{Symbol}) \quad (1)$$

And also the amount of the uncertainty that the source of the events generates is equal to:

$$H = -\sum(p_i \log_2(p_i))(\text{bits}) \quad (2)$$

From equation (2) it can be seen that the highest amount of uncertainty from an information source is realized when the output symbols of the source are equally probable.

The idea behind local entropy method is to divide the processed image into separate regions and then to analyze

each region separately as information source. The amount of entropy calculated for each region gives an overview about the level of correlation between individual blocks (bits) in the selected region.

B. Local Entropy in Iris Image Processing

A research by J.Daugman [2] has shown that in average the iris image has discrimination entropy of 3.2 bits/mm^2 which is indeed a suitably high value for identity recognition purposes and comparison based structures.

The process of deriving the local entropy of the image begins with the acquisition of the image, after this step the initial preprocessing is performed on the image to prepare the image for the main processing, after preprocessing, the extracted image is further processed for revealing its hidden features, After the features are revealed and enhanced, the local entropy segmentation process divides the obtained result into separate regions each containing a portion of the enhanced features, In this step, assuming each section as an information source, the entropy of each of the segments is separately calculated and finally the obtained entropy values are sorted to deliver the entropy function of the image.

In the next section the process that leads to the final derivation of the local entropy is described in detail. In the rest of the paper, unless stated, Fig. 1 is considered as the reference image.



Fig. 1 Reference image

III. PREPARING THE IMAGE FOR LOCAL ENTROPY METHOD

A. Classical Iris Segmentation

Typically the captured image as shown in figure (2) consists of different organs of the eye such as the eyelids, sclera and the pupil in addition to the iris. After the image is captured, the first step is to separate the part of the image related to iris from the image. Various methods for separating the iris image from the eye image have been proposed in image processing literature. Daugman's system [2] makes use of integro-differential operators as a means for separating the internal pupil and external sclera neighboring regions from the iris image. Li Ma's operator [4] makes use of combining Canny's operator with the Hough transform to locate the iris boundaries.

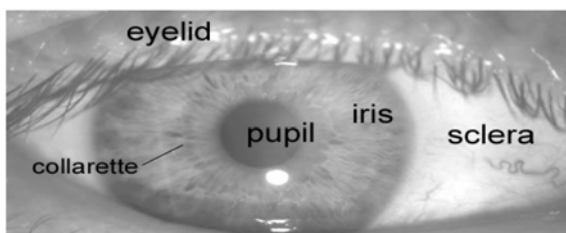


Fig. 2 Typical captured eye image [8]

Another less sophisticated yet efficient enough iris separation method is proposed by the authors in [5] based on detecting corners and curvatures using phase congruency method [6]-[9]. The result of applying the later method on the captured image is shown in Fig. 3.

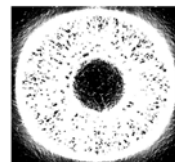


Fig. 3 Iris boundary extraction by Phase congruency method

In general iris segmentation is performed before the actual image processing. However the segmentation method proposed by the authors in this paper based on local entropy characters of the iris requires the image to be initially processed to reveal its high entropy regions. After describing the image enhancement method in the next subsection the proposed segmentation method will be explained and analyzed.

B. Edge Detection and Denoising

After the eye image is captured the process of feature enhancement should be applied to reveal and clarify the important features of the image. The features of most interest in this step of the process are the edges within the iris surface. Simultaneously the present noise in the image must also be wiped off. A contradiction arises here as both the edges in the image and the present noise consist of high frequency components. If the edges are to be intensified by normal enhancement methods, the noise components are strengthened accordingly and unwantedly. On the other side if one tries to wipe the noise off the image surface by weakening the high frequency components the edges of the image are blurred accordingly and of course unwantedly. A solution to this problem is to use the phase characteristics in exchange for the amplitude characteristics of the frequency components [5]. The visual result of applying the phase based method is shown in Fig. 4.

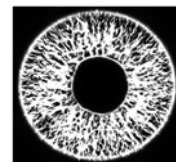


Fig. 4 The result of Edge detection and denoising of the reference image

C. Local Entropy Segmentation

After the important features of the image are enhanced it is time to apply the proposed local entropy method. Applying the method as mentioned in part B of section 2 on the reference image results in the local entropy plot as shown in Fig. 5.

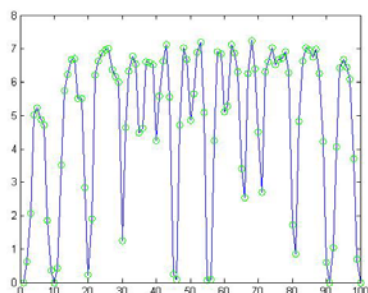


Fig. 5 Unsorted Local entropy in bits/segment, for 100 local segments of Fig. 4

Sorting the obtained results according to the amount of the entropy per segment results in Fig. 6.

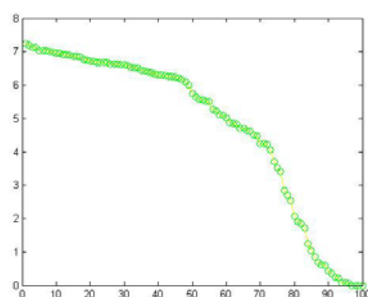


Fig. 6 Sorted Local entropy in bits/segment, for 100 local segments of Fig. 5

After the entropy of the surface is calculated it is the necessity of the application that dictates how much of the iris surface is to be segmented for the best performance. Another question that arises here is the size of the segmentation blocks. Apparently the finer the blocks are chosen the better the entire surface is segmented, however making the segmentation too small also results in the selection of the regions where image noise is still present as the presence of noise acts as a source of entropy in the region.

TABLE I
 EXPERIMENTALLY OBTAINED RESULTS FOR BEST SEGMENTATION AND SURFACE SELECTION

Application	No. of Segmentation blocks	Percent of sorted curve used. (From higher to lower entropy)
Biocryptosystem	100 (10 by 10)	10%
Comparison based purposes (in the presence of eyelashes in the image database)	900(30 by 30)	30%
Comparison based purposes (in the absence of eyelashes in the image database)	900(30 by 30)	50%

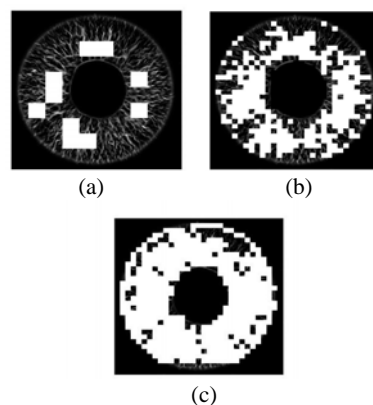


Fig. 7 (a) local entropy for 10 by 10 segmentation and 10% selection. Suitable for biocrypto purposes (b) local entropy for 30 by 30 segmentation and 30% selection. Suitable for burst error bearing comparison based purposes. (c) local entropy for 30 by 30 segmentation and 50% selection. Suitable for burst error free comparison based purposes

In biocrypto applications it is necessary not to let the phony regions to enter the process of key generation therefore experiment results show that the best practice in segmenting the iris for such purposes is to choose the highest entropy regions and to use large segments in order to prevent the noisy regions from masquerading themselves as the desirable regions. For comparison based purposes in which not every single bit, but the iris surface as a whole is important it is therefore a good practice to chose fine regions and also a larger portion of the entropy curve to segment the most of the iris surface.

Table I shows the results of experiments performed for choosing the best block size and percentage of the sorted entropy curve for different applications and square images.

Fig. 7 shows the obtained regions for different chosen block size and percentages of the surface suitable for different applications.

IV. APPLICATIONS OF LOCAL ENTROPY METHOD

As it has already been shown in the last section the local entropy method in iris image processing primarily acts as a segmentation method which is able to locate the iris inside an image by analyzing the entropy characteristics of the iris and the surrounding eye organs like pupil, Sclera and eyelids. Experiment results show that the local entropy characteristics of the iris are quite capable of separating the iris from surrounding Sclera and pupil. Because it is quite expectable that the surface of the pupil and Sclera has lower entropy compared with the high entropy surface of the iris. Therefore, when the sorted local entropy curve of Fig. 6 is segmented by proper thresholding, only the high entropy part which is mainly related to iris will be segmented. Although, the proposed segmentation method does not give the same output as of the classical segmentation methods it is suitable for many purposes such as iris based biocryptosystems.

The 2nd assumable application of the method is giving the designer a free hand in choosing the region mostly suitable for

the biocryptosystems applications. In designing a cryptosystem [3], less correlation between neighboring bits of a key string make the key unpredictable and consequently stronger. In designing biocryptosystems [3], it may be a good practice to consider only the upper part of the curve in Fig. 6, and therefore to choose the segmented iris in Fig. 7(a) as the reference image, Because, as it was shown in section 2 the higher entropy results in less correlation between neighboring bits and therefore stronger key strings are obtainable from the chosen regions. It is however evident that for typical comparison based approaches higher percent of the curve and therefore larger surface of the iris must be segmented as shown in Fig. 7(c).

One point that is necessary to be mentioned here is the potential weakness of the method at the presence of eyelashes in the captured image. As the eyelashes generally occur in the image with a random pattern, this pattern generally leads to unwanted uncertainty inside the image and therefore an undesired source of entropy is generated by the eyelashes. Moreover in designing biocryptosystems, the presence of eyelashes are modeled as channel burst errors [3] and to overcome their negative effects it is necessary to sacrifice a great deal of system capacity for covering the effect of burst noise. Therefore it is necessary to detect those areas of the image affected by the presence of eyelashes and put them in the blacklist. Various eyelash detection methods have been proposed in iris processing literature from which the method proposed by Kong and Zhang [7] is chosen by the authors for its efficiency and ease of implementation. The effect of combining eyelash prevention schemes with the rest of the image processing process will be discussed in the next section.

Thus the local entropy curve of the iris image is obtained for practical purposes. In the next section the potential applications of the obtained data are introduced.

In order to analyze the efficiency of the scheme in overcoming the negative effects of burst noise the biocryptosystem proposed in [3] has been redesigned with the local entropy based code generation taking the place of the original iris code, Fig. 8. The original design of the biocryptosystem in [3] is based on initially generating a random key string in the key generation unit, after this step by applying error correction coding and burst correction coding the key string is made both suitable for combination with the iris code and is strengthened against possible code errors, during the authentication process the same procedure is applied on the received image and the generated code is Xored with the previously saved code to reveal the coded key string. Now should the errors between the received and reference images be in an acceptable range the decoding process would reveal the original key. In the scheme the burst correction coding is mainly used to overcome the effect of eyelashes and light spots.

In order to analyze the noise prevention ability of local entropy method the burst error correction coding in the original system is omitted. The CASIA image database [10] has been used for deriving the output statistics. Table II shows the results.

Analyzing Table II from the prospect of the burst error detection capability of the system reveals that though the data that enter the error correction coding (ECC) module are quite erroneous the simple Hamming ECC which is not capable of correcting burst errors manages to reduce the FRR from the order of 20% before decoding to the acceptable order of 1.5% after applying the decoding module. The logic deduction that can be made from the above fact is that the local entropy method as the image processing unit combined with eyelash detection method has managed to prevent the negative effects from spoiling the key recovery process otherwise the negative effects would have revealed themselves in the output.

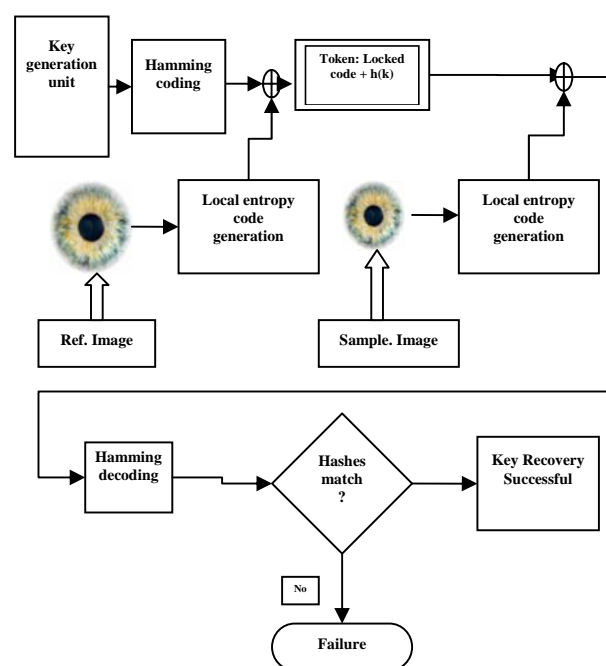


Fig. 8 Block diagram of biocryptosystem of [3] adopted for the paper purposes

TABLE II¹
 FALSE REJECT RATE FOR LOCAL ENTROPY METHOD FOR DIFFERENT KEY LENGTHS

Length of biocrypto key	FRR% before applying error correction coding(Hamming)	FRR% after applying error correction coding(Hamming)
224	16.6	1.6
210	23.6	1.3
196	29.3	2
182	31.3	1.3
168	24	2.6
154	22	1.3
140	23	1.6

¹ It must be noted and emphasized here that the results brought in Table II are strictly for qualitative comparison, and as the image database used in [3] is unknown to the authors of this paper no quantitative comparison between the results in this paper and reference [3] is logically valid.

V. CONCLUSION

A novel iris segmentation method based on the local entropy features of the iris has been proposed in this paper. Considering the comparably less computational needs than the custom segmentation methods, the method is also capable of giving the designer a free hand in choosing which part of the iris he or she wants to work on. Experimental results show that the method is quite successful in satisfying the expected application needs.

ACKNOWLEDGMENT

This paper is supported by Iran telecommunication research center under the contract agreement number T/500/15050.

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