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BIOMETRIC IDENTIFICATION OF INDIVIDUALS BY THE MORPHOLOGICAL PROCESSING OF THE IRIS*

IDENTIFICAÇÃO BIOMÉTRICA DE INDIVÍDUOS ATRAVÉS DO PROCESSAMENTO MORFOLÓGICO DA ÍRIS

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ABSTRACT

A new approach based on morphological operators is presented in this paper for application of biometric identification of individuals by segmentation and analysis of the iris. To segment the iris region from the eye image and also to highlight chosen iris patterns were developed algorithms based on morphological operators. The extracted features are used to represent and characterize the iris. In order to properly extract the desired patterns, an algorithm is proposed to produce skeletons with unique paths among end-points and nodes. The representation obtained by the morphological processing is stored for identification purposes. To illustrate the efficiency of the morphological approach some results are presented. The proposed system was developed to present low complexity implementation and low storage requirements.

Key words: Biometric identification, morphological processing, segmentation and analysis of the iris

1. Introduction

In the last decade the verification and identification of individuals by biometrics have attracted a lot of attention. The human iris has been used in automated recognition systems, as well as others biometrics, for this purposes. Since its characteristics are unique to each individual and stable with age, the iris has a great potential use in the biometric noninvasive evaluation [10, 18].

In a study conducted by the National Physical Laboratory (NPL) on behalf of the Communications Electronics Security Group [20], the iris recognition beat six other biometric systems, including facial recognition, fingerprint, and vein and voice recognition. The iris

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recognition technology registered a false match rate of zero in more than 2.7 million comparisons. It also had a false rejection rate of just 1.8%, with no users getting a false rejection after three attempts. This was the lowest false rejection rate of the systems tested, with four of the others tested - including facial recognition, registering a ten to 25% false rejection rate. The objective of the study was to accomplish an independent and objective evaluation comparing all viable biometric technologies.

Iris recognition systems can be implemented using several types of approaches. Some of them are described as follows.

The system proposed by Daugman [6, 8, 18] uses an integro-differential operator to locate the borders of the iris, based on the ascension of the gradient to adjust the circular contours. The encoding (representation) of the iris it is done through the application of the 2D Garbor wavelet and to measure the dissimilarity between the irises, the Hamming Distance is computed between the corresponding pair of iris representations.

Wildes's [18] system uses border detection based on the gradient and Hough Transform to locate the iris in the image. The representation makes use of a band-pass decomposition derived from application of Laplacian of Gaussian filters, implemented in the practice by the Laplacian Pyramid. The degree of similarity is evaluated with base on normalized correlation between the acquired and database representations.

The algorithm proposed by Li Ma [11] *et al*. uses a bank of Gabor filters to capture both local and global iris characteristics to form a fixed length feature vector. Iris matching is based on the weighted Euclidean distance between the two corresponding iris vectors and is therefore very fast.

Shinyoung [12] *et al*. uses a approach to making a feature vector compact and efficient by using Haar wavelet transform, and two straightforward but efficient mechanisms for a competitive learning method such as a weight vector initialization and the winner selection.

The system proposed by Tisse [4] *et al*. uses gradient decomposed Hough transform / integro-differential operators combination for iris localization and the "analytic image" concept (2D Hilbert transform) to extract pertinent information from iris texture.

Boles [19] uses the Wavelet Transform zero crossings for extracting features from images of the iris and representing them, by fine-to-coarse approximations at different resolution levels, calculated on concentric circles in the iris, to generate a sign one dimensional (1D). These signs are compared with the model's features using different dissimilarity functions.

The extraction of features can be implemented through several different techniques [6, 7, 17, 18]. However, the choice of the feature, as well as of the technique to be used, should take into account the contribution in terms of information that can be obtained from it. In other words, the choice of a certain feature depends on its capacity for separating patterns.

With this objective, the approach based on *morphological operators* [1, 2, 5, 9, 16, 17] is used to identify existent patterns in the iris. The basic idea consists of highlighting these patterns, applying a certain sequence of these operators to obtain the structures and to arrive into a representation, from where the information will be extracted to characterize them. The proposed representation allows to storage the obtained information in a compact and efficient way, while the use of the morphological operators presents advantages in terms of low computational complexity (processing time) and integration hardware issues.

2. Applications

Systems of iris recognition are being used in several sectors and in different applications as for example: control access to bank accounts (in ATM's), tracking prisoner movement, authenticating online purchases, control of people's access to documents, safes, files, meeting rooms, administrative centers, management and control rooms, airports and ports, high-security installations (military, nuclear, laboratories, factories, etc), etc.

3. Automated iris recognition

The process of automated iris recognition basically includes the acquisition of the image, the localization of the region of interest (*ROI*), the extraction and the matching of patterns [1, 15, 18]. Several factors can affect the quality of the image, and consequently, in the decision to be taken, which determines if the iris pattern submitted to the system matches or not to a previously stored pattern.

In the stage of acquisition of the image, it is one of the largest challenges for the systems of automated iris recognition: to capture an image of high quality by noninvasive means to the user. In other words, to obtain an image with enough resolution and sharpness to support the recognition, with a good contrast in the interior of the iris (without resorting to an illumination that causes discomfort to the user) and still well framed (without forcing the user excessively).

Supposing that the acquisition was accomplished in controlled conditions (illumination, distance, framing, etc.), in order to obtain images with the best quality (resolution, sharpness and contrast), a pre-processing stage is required. This stage is necessary to enhance certain structures of the iris, to eliminate undesirable effects (e.g., reflections), and still to determine the *ROI* (located in the portion inside of the *limbus* - border between the *sclera* and the iris - and outside the *pupil* –

Figure 1), due to the fact that the acquired image does not include only the iris, but it also contains data from the surrounding region of the eye.

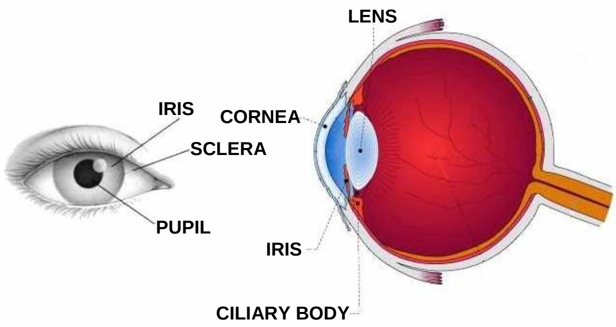


Figure 1 - Anatomy of the human eye.

The iris can suffer a partial occlusion of the eyelids, causing an alteration in the limits of the ROI, which should include the area located between the eyelids (below the upper eyelid and above the lower eyelid). Other factors can influence in the location of the iris, as the low contrast between a heavily pigmented iris and its pupil, the variation in the eyelid contrast (depending on relative pigmentation between the skin and the iris), irregular boundary of the eyelid and the presence of eyelashes. Therefore, these factors suggest that the location of the ROI must be sensitive to a wide range of edge contrasts, robust to irregular borders, and capable of operating with variable occlusion.

After located the ROI in the acquired image, it is necessary to identify and to extract the existent patterns in the iris. So that the comparison of patterns can be accomplished with success, the image containing the iris submitted to the system - Figure 2(b), it should be aligned with the "image" stored in the database - Figure 2(a), with which will be compared. The alignment enables a more detailed comparison, because it allows establishing a more precise correspondence among the structures disposed along the images.

The Figure 2(c) illustrates the effect caused by the overlapping of the images, without the due movement compensation. The arrows indicate the areas where there would not be overlapping, what it would cause loss of information of the structures located in these areas. In Figure 2(d) the image submitted to the system was compensated, with base in the "image" stored in the database. This alignment should compensate the effects of the translation (lateral shift in any direction in a parallel plan to the lens of the camera), scaling (variation of the distance between the camera and the eye) and rotation (deviation in the angular position about the optical axis of the camera).

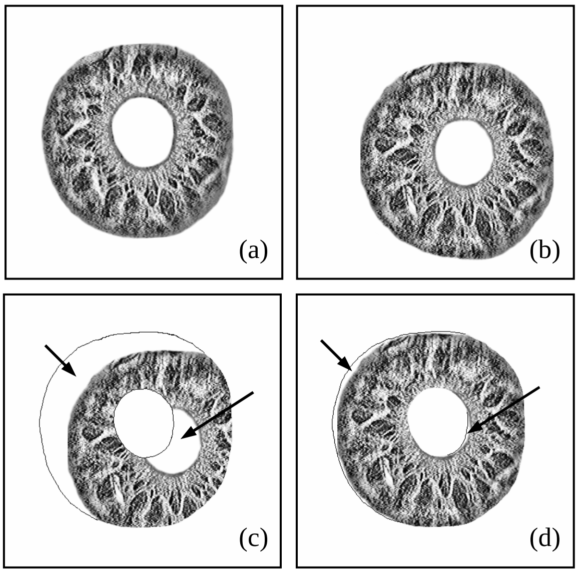


Figure 2 - Alignment of the iris images.

The term morphology in Biology refers to the study of the structure of plants and animals. Similarly, the *Mathematical Morphology* is based on the study of the geometric structure of the entities that compose an image [2, 5, 9, 16, 17], thus, being adequate to the proposed approach. The representation obtained through the morphological processing is based on *connected components* [5, 9, 16, 17].

Due to great amount of spatial characteristics of the human iris, which are manifested in a variety of scales [18], the choice of the representation affects directly the quantity of information to be stored. In the proposed approach, the representation is based on the information of the *end-points* (extreme points), of the *nodes* (points from where the ramifications start) and of the *branches* – Figure 3.

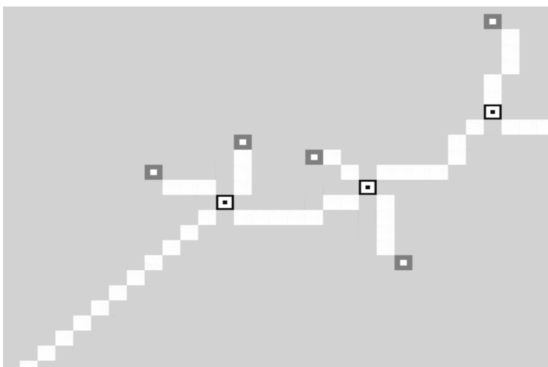


Figure 3 - Representation: *end-points* (▣) and *nodes* (▣).

With this representation the quantity of necessary information to characterize the iris is small, when compared to another representation types, generating a compact representation (of the order of hundreds of bytes) for easy storage. The image of the iris is not stored, only the representation is kept.

Figure 4 presents the diagram of the proposed iris recognition system.

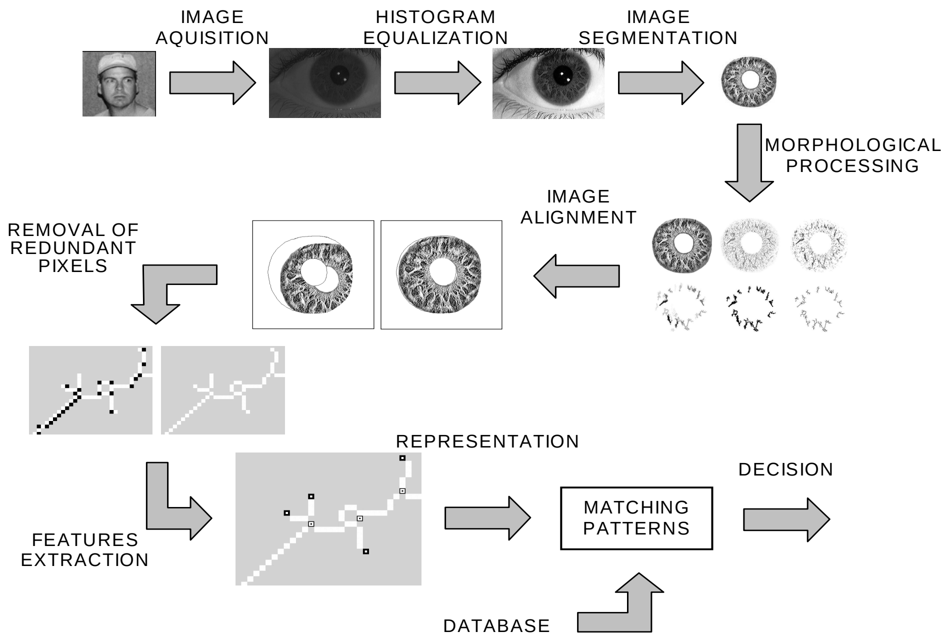


Figure 4 - Iris recognition system – diagram.

4. Morphological operators

4.1 Mathematical Morphology

In the Mathematical Morphology [1, 5, 9, 16, 17], information relative to the topology and geometry of an unknown set (e.g., an image), are extracted using another completely defined set called *structuring element* (*SE*). Then, the set theory is the base for the Mathematical Morphology.

4.2 Some morphological operators - Description

Area Opening [5, 13, 16] removes any connected component with area less than λ of a binary image *F*. For gray-scale images (f: $F \rightarrow \overline{R}$), it is generalized by applying the binary operator successively on slices of the image *F* taken from higher threshold levels to lower threshold levels:

$$\gamma_{\lambda}^{a}(f) = \bigvee_{S \in A_{B,\lambda}} \gamma_S(f) \quad (1)$$

$$A_{B,\lambda} = \{X \subset F : X \text{ is } B \text{ connected}, Area(X) \geq \lambda\}$$

Close-by-reconstruction Top-hat creates an image by subtracting the image *F* of its closing by reconstruction, defined by two *SE*: one to dilation (B_{dil}) and another to connectivity (B_c).

$$\varphi^{rec\,th}(F) = \varphi^{rec}_{B_{dil},B_c}(F) - F \quad (2)$$

The image *reconstruction* [9, 14] can be made by an infinite sequence of dilation and intersection (called *conditional dilation*). The *grayscale reconstruction* $\rho_G(F)$ of G from F is obtained by iterating grayscale *geodesic dilations* [14] of F "under" G until the result reaches stability:

$$\delta_{B,G}(F) = \delta_B(F) \wedge G \quad (3)$$

$$\delta^n_{B,G}(F) = \underbrace{(\delta_{B,G}(\delta_{B,G}(\ldots\delta_{B,G}(F)))}_{n\ times} \quad (4)$$

$$\rho_{B,G}(F) = \bigvee_{n \geq 1} \delta^n_{B,G}(F) \quad (5)$$

The *close top-hat* [9, 13, 14] is the difference between the close image and the original.

$$\varphi^{th}(F) = \varphi_B(F) - F \quad (6)$$

Thinning creates a binary image by performing a thinning of the binary image F. Each iteration is performed by subtracting the points that are detected in F by *hit-or-miss* operators [5, 9, 16, 17], characterized by rotations of 45°.

Threshold [9, 17] creates a binary image as the threshold of the image F by values $t1$ and $t2$. A pixel has the value **1** when the value of the corresponding pixel in F is between the values $t1$ and $t2$.

5. Pre-processing

The eye image acquired (in color) and converted to *gray-scale* is submitted to a pre-processing for enhancement and improvement of the contrast using *histogram equalization* [17] – Figure 5. In the Figure 5(a), the eye image before of the *histogram equalization* and in 5(b) after the processing.

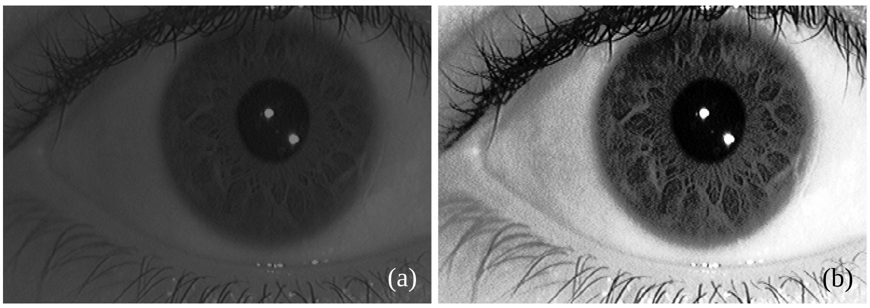


Figure 5 - Histogram equalization.

An algorithm based on *thresholding* and on morphological operators is used to segment the eye image and obtain the ROI, the iris region. Initially one detects the inner border (iris / *pupil*), whose sequence of operators applied is: *threshold*, *area opening* and *closing*. Following one detects the external border (iris / *sclera*), whose sequence of operators applied is: *threshold*, *closing*, *area opening*. The result is presented in the Figure 6.

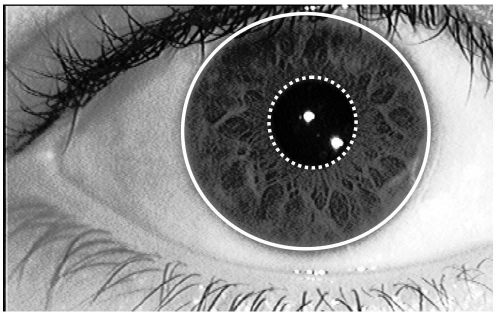


Figure 6 - Borders of the iris: inner border (dotted circle) and external border (continuous circle).

With the information of the inner and external borders, that segments the region of the iris, the pixels of the image that are out of the *ROI* are discarded and the segmentation stage is ended.

6. Morphological processing

6.1. Sequence of morphological operators

The iris image, after the pre-processing, is submitted to a sequence of morphological operators, with the goal of identifying patterns in it. Operators as *dilation*, *erosion*, *opening* and *closing*, are associated to evidence these patterns [5, 9, 17].

Initially operators are applied to the iris image (Figure 7-1), still in gray-scale, highlighting the existing structures as a whole (Figure 7-2 - *Close-by-reconstruction Top-hat* and 7-3 - *Opening*).

Then an operator that removes structures in according to its size (area) is applied, resulting in an image with the structures disposed in layers (Figure 7-4 - *Area opening*).

Due to the structures disposition, a *thresholding* is applied to obtain a binary image, where only the relevant structures appear (Figure 7-5 - *Threshold*).

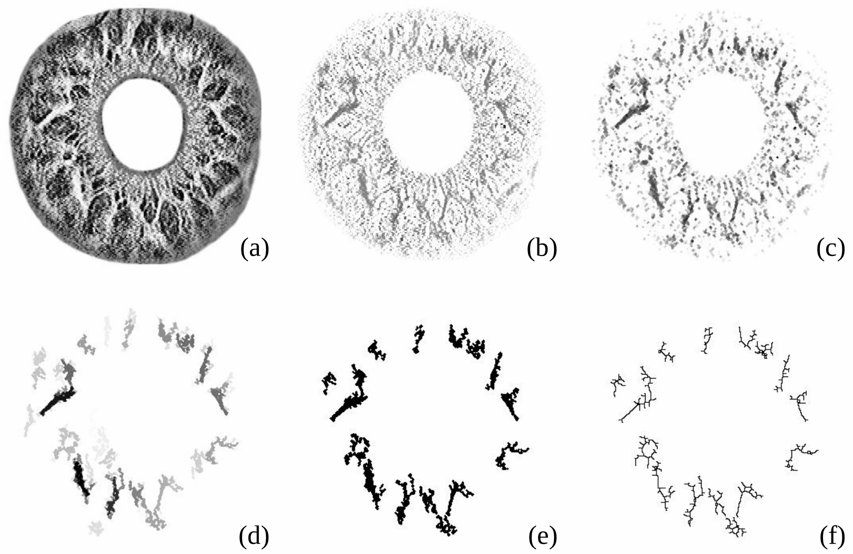


Figure 7 - Sequence of morphological processing.

This image is submitted to a normalization, that takes as reference an image containing *pseudo-structures* – Figure 8(b), reconstructed from the representation (coordinates of the *end-points* and of the *nodes* – Figure 8(a)) of the reference iris, which was previously stored in the database. The compensation of the effects caused by the translation, rotation and scaling, are made through an algorithm based on the *affine motion transform* [1, 3]. This movement compensation is necessary to adjust the image for the *matching* stage.

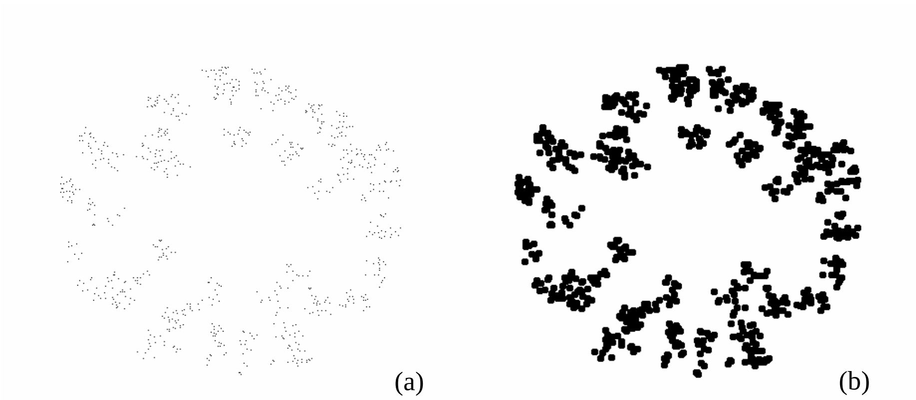


Figure 8 - Reconstructed image: (a) *end-points* and *nodes*, (b) *pseudo-structures*.

In order to arrive at an appropriate representation the structures should still go through a *thinning* process [5, 9, 16, 17], because the structures present themselves as an agglomerate of pixels (Figure 7-6 - *Thinning*).

However, after the *thinning*, the structures present a considerable amount of *redundant pixels* that hinders the task of identification of the *end-points* and of the *nodes*, which are the base of the adopted representation. Figure 9 shows part of the skeleton of a structure, where the *redundant pixels*, the *end-points*, and the *nodes* can be observed.

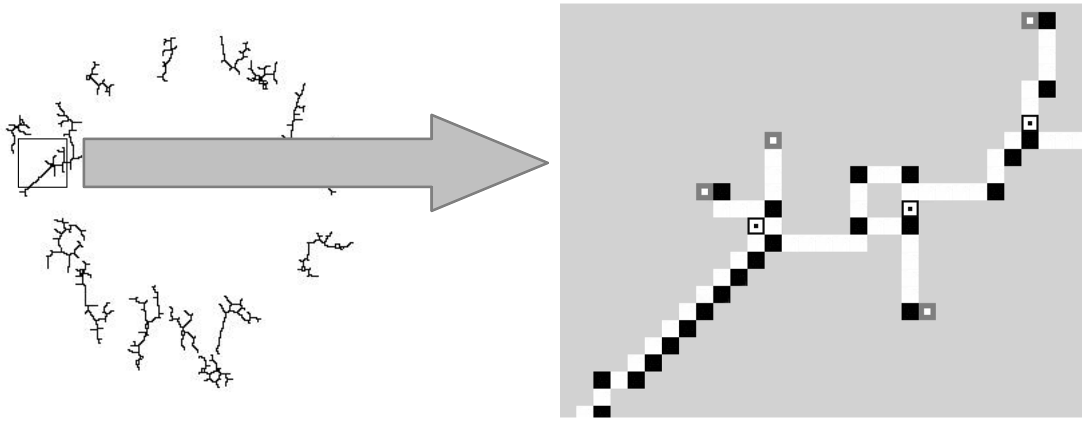
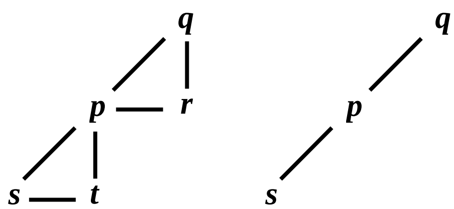


Figure 9 - In the detail: *redundant pixels* (black), *end-points* ( ) and *nodes* ( ).

The principle, of the algorithm developed to eliminate redundant pixels, consists of determining paths, such that, for two adjacent pixels (Figure 10(a): ***s*** and ***p*** or ***p*** and ***q***) a single path that connects them exists – Figure 10(b).



(a) (b)

Figure 10 - Paths: (a) multiple paths and (b) single path.

However, the elimination of the redundant pixels cannot cause any connection break (gap) in the structure of the pattern, fact this very common one in the algorithms of conventional skeletonizing – Figure 11. The developed algorithm makes a verification of the neighborhood of the pixel that is being analyzed, to guarantee that the existent connections will be preserved.

Another important factor is substantial reduction of the error, provided by the use of the algorithm of elimination of the redundant pixels, without which the process of matching of the representation would not be possible.

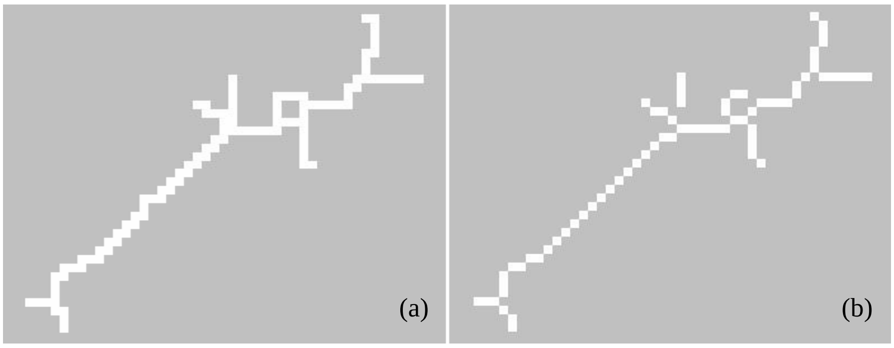


Figure 11 - (a) structure of the pattern with *redundant pixels* (b) gaps in the structure.

6.2. Redundant pixels - removal algorithm

An algorithm was developed to eliminate the *redundant pixels* and to avoid gaps in the structure connection.

In relation to the disposition of the pixels in the neighborhood of *p*, the notation adopted (Figure 12) to represent them is the following:

N_i : pixel belonging to the 4-neighbors of the pixel *p*;

D_i : pixel belonging to the diagonal neighbors of the pixel *p*.

(a)

D_2		D_1
	p	
D_3		D_4

(b)

	N_1	
N_2	*p*	N_4
	N_3	

(c)

D_2	N_1	D_1
N_2	*p*	N_4
D_3	N_3	D_4

Figure 12 - Notation: (a) diagonal neighbors, (b) 4-neighboors and (c) 8-neighboors.

To eliminate the *redundant pixels* two types of *SEs* are used ***SE-1*** and ***SE-2*** (Figure 13(a) and 13(b)) and their respective rotated versions of 90° - clockwise - ***SE-1r*** and ***SE-2r*** (Figure 13(c) and 13(d)).

(a)

1		
	1	1
	1	

(b)

		1
1	1	
	1	

(c)

	0	1
	1	

(d)

1	0	
	1	

Figure 13 - *SEs* used for elimination of the *redundant pixels*.

The basic principle of the algorithm is similar to the operation *hit-or-miss*, which is calculated by translating the origin of the *SE* to each possible pixel position in the image, and at each position comparing it with the underlying image pixels.

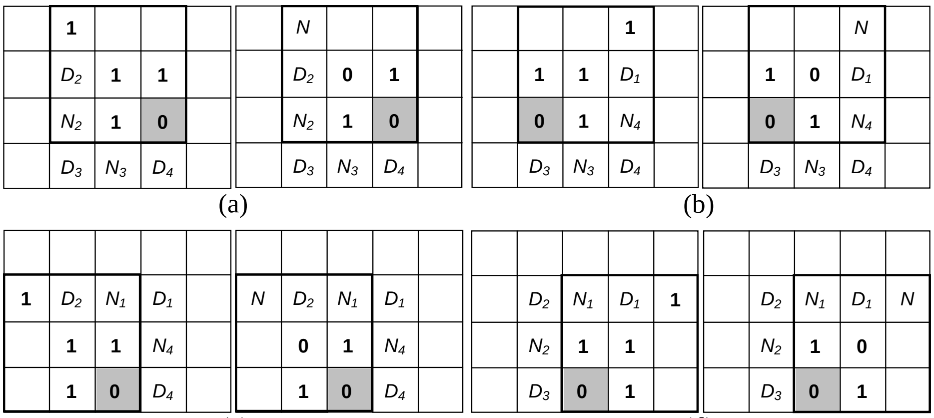
The difference is that in the algorithm, when foreground and background pixels in *SE* exactly match with the pixels in the image, the pixel to be modified is not more the image pixel underneath the origin of *SE*. The pixel to be modified depends on the *SE* that is being used. In Figure 13, for each *SE*, these pixels are represented in highlight (gray background). Then, when there is a match of the pixels, the pixel being analysed (gray background) will receive the value **0**.

The algorithm for elimination of *redundant pixels* begins a scanning in the image to search pixels with value equal to **1**. When a pixel (*p*) in this condition is found, the verification of the pixels located in their neighborhood begins. The Table 1 presents the steps of the verification sequence, showing the pixels of the neighborhood of *p* on which the origin of *SEs* must be positioned, the applied *SEs*, the modified pixels and the corresponding figures (Figure 14).

After having finished the verification, the pixels that had their value substituted by **0** during the process are altered in the image and the scanning continues. In the Figure 14 the positioning of the *SEs* appears in highlight (borders in bold).

Table 1 - Steps of the verification sequence.

Step	**Origin of the *SE***	**Applied *SEs***	**Modified pixel**	**Figure X**
1	N_1	***SE-1*** ***SE-2***	N_4	(a)
2	N_1	***SE-1r*** ***SE-2r***	N_2	(b)
3	N_2	***SE-1*** ***SE-2***	N_3	(c)
4	N_4	***SE-1r*** ***SE-2r***	N_3	(d)



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

Figure 14 - Verification sequence.

The result of the application of the algorithm can be seen in the Figure 15, where the redundant pixels are eliminated without causing any connection break in the structure.

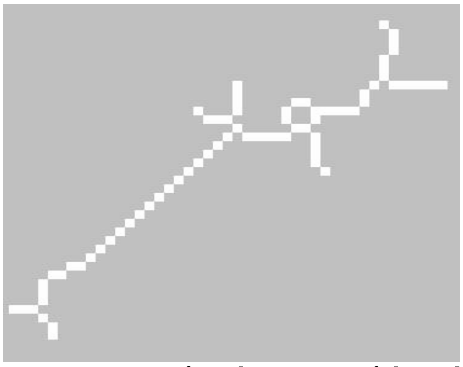


Figure 15 - Structure after elimination of the redundant pixels, without connection breaks.

6.3 Representation and matching

After eliminating the *redundant pixels* of the image containing the skeletons of the structures, the next stage consists of identifying the *end-points* and the *nodes*.

The identification process begins with the verification of the 8-neighbors of the pixel *p*, $N_8(p)$ – Figure 12(c). Since an *end-point* is a pixel located in one of the extremities of a *branch*, if one of the pixels of $N_8(p)$ is equal to **1**, then the pixel is an *end-point* - Figure 16(a).

However, to identify a *node* it is necessary that three or more pixels of $N_8(p)$ are equal to **1**, and if in a radius of 3 pixels there are other *nodes* - Figure 16(b), the medium point among the *nodes* is calculated, and these coordinates will correspond to the *medium node*, that will substitute the others - Figure 16(c).

Then one makes a mapping of the coordinates of the *end-points* and of the *nodes*, and after that starts the matching stage, which is based on the proposed representation. The coordinates of the *nodes* are matching to the coordinates of the *nodes* of the reference iris (database), in order to identify the *coincident nodes*. Starting from the coordinates of the *coincident nodes*, its ramifications are verified to obtain the *number of branches for coincident node*.

After the referring information to the coordinates of the *coincident nodes* and the *number of branches for coincident node* are analyzed, one verifies if the processed iris is the same as the one that was taken as reference, or not.

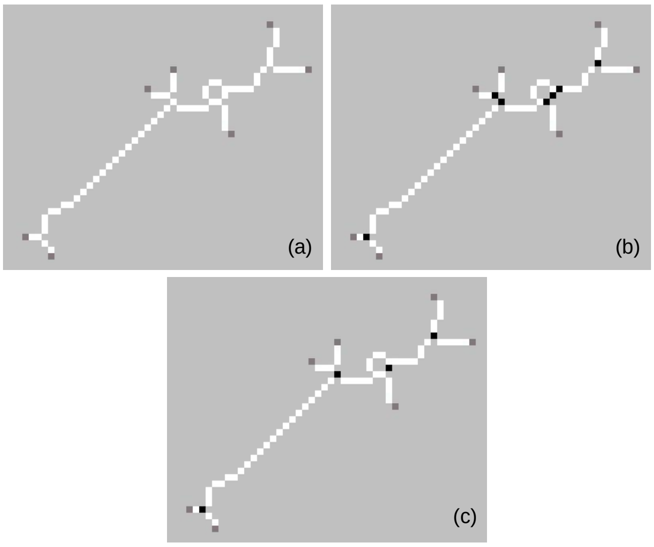


Figure 16 - Identification: *end-points* (gray), *nodes* (black).

7. Methodology and experimental results

The proposed method was tested with real images, acquired in colors and from both eyes, and later converted to gray-scale, because the proposed approach is based on the extraction of structural patterns found in the iris and not on their color.

To create the experimental database, used for the simulations, several images were selected (170) at random among hundreds of images of both eyes, of many individuals, and acquired in several occasions, without imposing restrictions to the user regarding to positioning (distance from the camera, rotation of the head and position of the eye). Since images are not stored in the database, but the information corresponding to its representation, all images are previously processed.

The representation used to build the database takes into account only the iris patterns of an eye (right or left). Being like this, the database is divided in *ID* (iris of the right eye) and *IE* (iris of the left eye). Therefore, the images submitted to the processing must belong to the same eye of the correspondent iris in the database.

Several phases of tests were accomplished with the objective of to optimize the information stored in the database, in the sense of storing the smallest amount of data possible, enough to allow the alignment of the irises, as well as its comparison based on the representation.

The methodology used in these phases of tests, for accomplishment of the experiments, is presented in the diagram of the Figure 17. In it can be observed two different stages, one that it accomplishes comparisons between a same individual's irises and another of different individuals. To each accomplished experiment the comparison is made with base in the coming information of the representation.

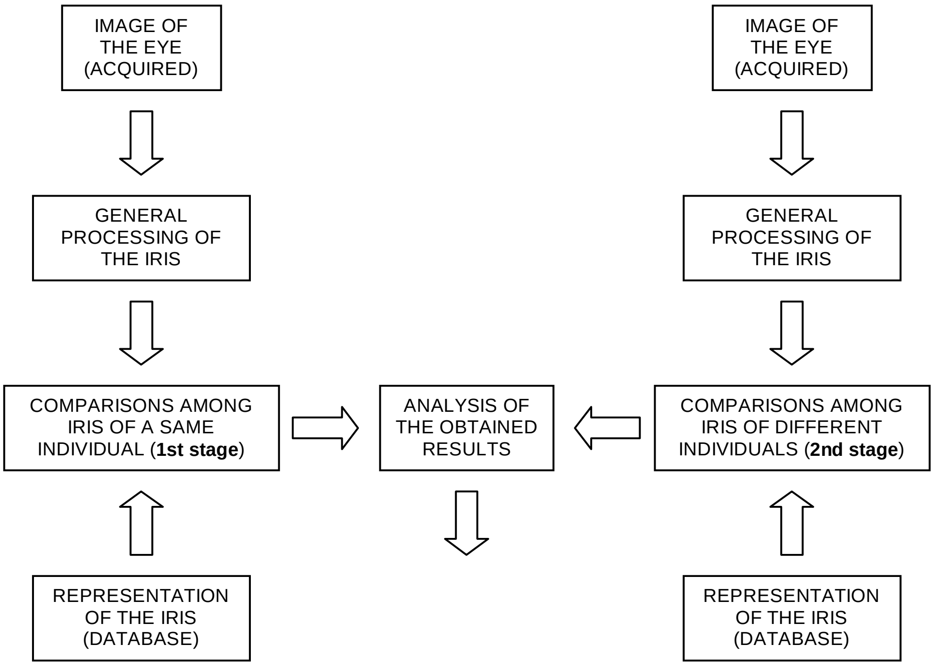


Figure 17 - Diagram – methodology.

The series of experiments were accomplished using for the alignment algorithms that operated with the binary image containing the structures, obtained after the application of the operator threshold. However, the image taken as reference (database), was the composed of pseudo-structures reconstructed starting from the representation of the iris. The Figure 18 presents the diagram of the adopted procedure and in highlight (dotted line) the content stored in the database.

In both stages of the experiments, several irises of four individuals (represented by the numbers 1, 2, 3 and 4 in Figures 19 and 20) were used. In the first stage the same individual's irises were compared to each other, and the procedure was repeated for the irises of the other three individuals. In the second stage the comparisons were made among the four individuals' irises, taking an iris of an individual as reference and comparing to the irises of the others.

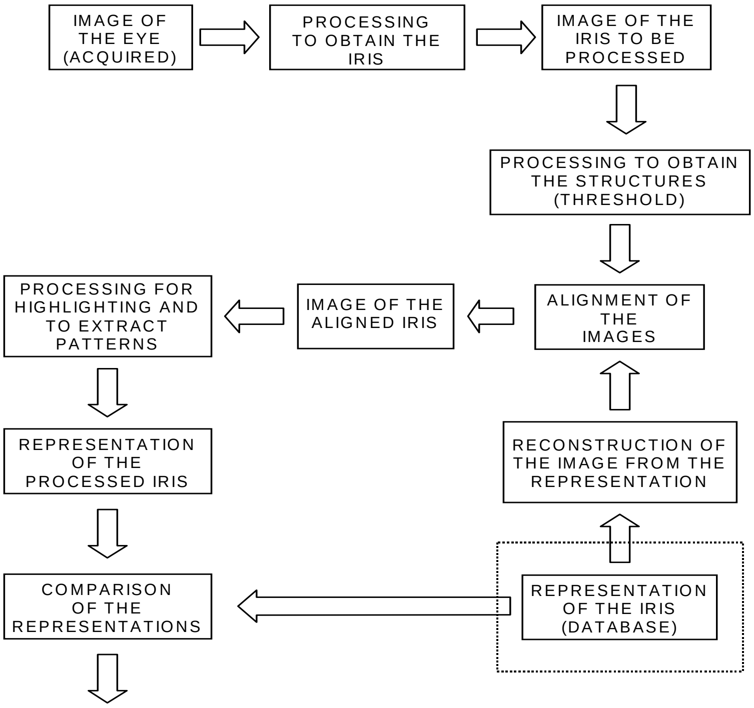


Figure 18 - Diagram of the procedure adopted for the experiments.

The result of one of the series of experiments is presented in the Figures 19 and 20. In the first stage were made 26 comparisons and in the second stage 76 irises comparisons. In Figure 19 the comparisons are accomplished based on the information of the *coincident nodes*, while in Figure 20 the information are originated from the *number of branches for coincident node*.

In Figures 19 and 20, it is clear the distinction that exists when comparing the representation of the same iris (1st stage) to the different irises (2nd stage), where the transition separates the two stages of the experiment. Based on the analysis of this information, it can be inferred if the image of the processed iris belongs or not to the same individual whose iris was taken as reference.

During the several phases of tests, some algorithms were evaluated. In terms of performance, all of them presented good results, being shown efficient in what says respect to the discrimination capacity, that is to say, the efficiency of the proposed approach for the iris recognition. The difference among them is related to the type of information stored in the database. The storage of the representation showed to be more adequate in terms of size, being possible starting from the representation to accomplish so much the alignment as the comparison of the irises. Through the analysis of the obtained results it was possible to verify that the compromise "*size* x *distinguibility*" was respected.

The representation of the structures based on the *end-points* and *nodes* showed to be adequate to characterize the existent patterns in the iris, allowing its *distinguibility* through the comparison of the information obtained from them, which was confirmed through the simulations accomplished with several images of iris.

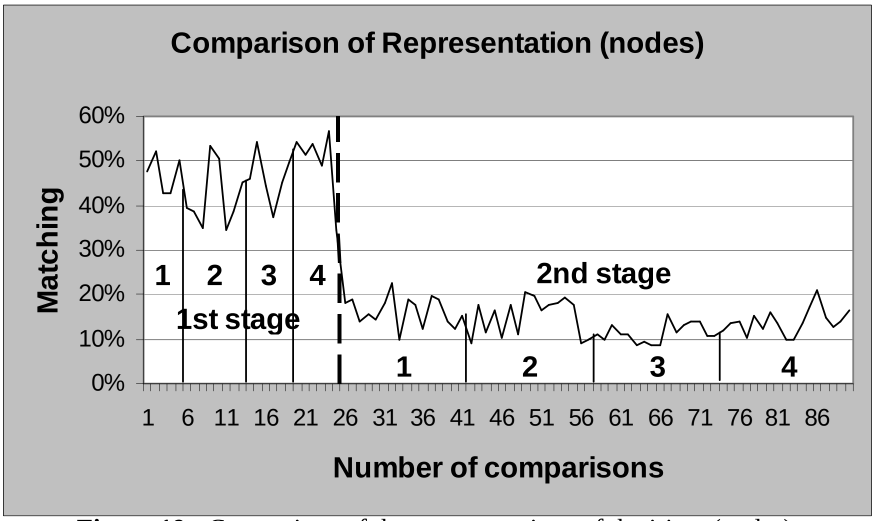


Figure 19 - Comparison of the representations of the irises (nodes).

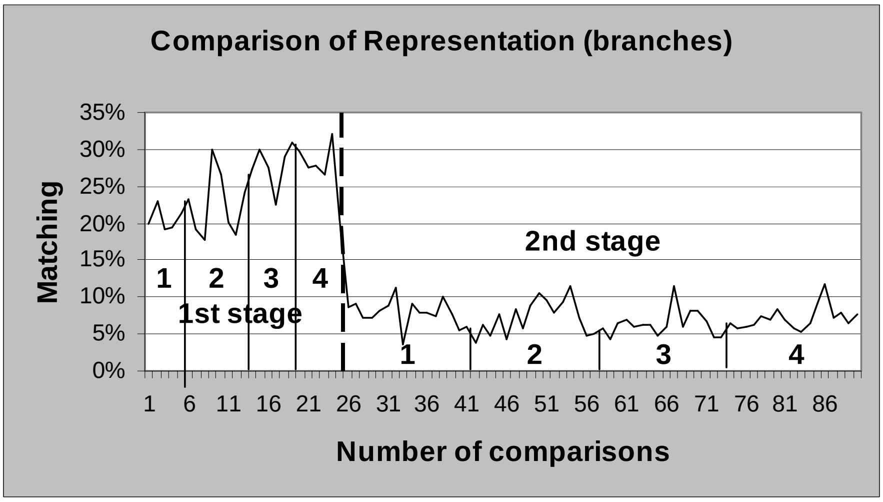


Figure 20 - Comparison of the representations of the irises (branches).

As to the size, the adopted representation is compact, on average 750 bytes for vector of information (*coincident nodes* and *branches for coincident node*). The size of the representation could still be reduced more, in case it is used some type of algorithm of data compression. Some tests showed that the size of the representation easily could be reduced to 1/3 of the original size.

Due to the representation type adopted, the processing time of the matching stage is reduced, being necessary only one operation that makes the matching among the vectors that contain the coordinates of the *nodes* and *coincident branches*. The same happens with the use of algorithms based on morphological operators, which basically use six operators in the several stages of the process, which also contributes to a reduction of the total processing time.

Even though only two types of information (*coincident nodes and number of branches for coincident node*) were used in this experiment, others could be used, increasing the system reliability, as well as the robustness of the representation.

In relation to the problem of occlusion of the iris, generally provoked by the eyelids and eyelashes, its effects are minimized due to the disposition of the structures in the iris and the form with that the algorithms process these information. The loss of information caused by the occlusion is not generally enough to compromise the performance of the algorithms, because the other areas of the iris those are free contain enough information to allow comparisons with considerable accuracy.

To proceed to the statistical validation of the proposed approach, the used database should be composed by a larger number of iris images, of different individuals. For this, it would be necessary to dispose of an equipment to do the acquisition of the images, as well as of the associated apparatus. However, as this project didn't dispose such resources, the validation of the approach was restricted to the available database, which was adequate to show the behavior of the used algorithms.

8. CONCLUSION

The results obtained validate the approach applied to the proposed application, and also show its potential for other applications.

The representation stored in the database showed to be adequate in terms of size (low storage requirements for the data representation of the patterns extracted), being possible starting from the representation to accomplish as much the alignment as the comparison of the irises. Tests using algorithms of data compression are being accomplished with the objective of to reduce the size of the representation.

The morphological approach proposed for this application, substituted with success other more usual techniques in the several stages of the processing (location of the iris, segmentation, features extraction, etc.), presenting low computational complexity (processing time).

The algorithm performed very well in terms of discrimination capacity for the set of images used. New tests are being accomplished with the use of iris images coming of another databases. The results up to now obtained, show that the performance of the algorithms is maintained. The proposed work provided an efficient morphological approach for application in biometric identification of iris.

RESUMO

Uma nova abordagem baseada em operadores morfológicos é apresentada neste artigo, para aplicações de identificação biométrica de indivíduos através da segmentação e análise da íris. Para segmentar a região da íris da imagem do olho e também evidenciar determinados padrões da íris foram desenvolvidos algoritmos baseados em operadores morfológicos. As características extraídas são usadas para representar e caracterizar a íris. Para extrair corretamente os padrões desejados, um algoritmo é proposto para produzir esqueletos com caminhos únicos entre *end-points* e *nós*. A representação obtida pelo processamento morfológico é armazenada para propósitos de identificação. Para ilustrar a eficiência da abordagem morfológica alguns resultados são apresentados. O sistema proposto foi desenvolvido para apresentar baixa complexidade de implementação e baixas exigências de armazenamento.

Palavras chaves: Identificação Biométrica, Processamento Morfológico, segmentação e análise da íris

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