EVALUATING THE SEGMENTATION STAGE OF AN IRIS RECOGNITION SYSTEM WHEN COMPRESSED IMAGES ARE USED

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Abstract - The objective of this work is to investigate the impact of a severe compression of iris images on the segmentation stage of an automatic iris recognition system. The efficiency of the algorithm which localizes the iris is essential to guarantee the credibility of the biometric recognition. This is the first stage that can be influenced by the quality loss of the images to be processed. Fractal compression and JPEG2000 compression were applied to a public iris images database. Two traditional methods which localize the circular borders of the iris and a method for detection of eyelids and eyelashes were applied to the compressed images and their efficiencies were evaluated. The results obtained with the simulations, when the images were submitted to several compression levels, lead to the important conclusion that segmentation stage does not represent a barrier for the utilization of compressed images in an iris recognition system.

Keywords - Biometry, Iris recognition, Iris segmentation, JPEG2000 compression, Fractal compression.

I. INTRODUCTION

An iris recognition system performs the processing of the image of the eye in several stages. The first processing stage is the localization of the iris region in an eye image. After this, the iris region is usually normalized to deal with dimensional inconsistencies, and then, the feature encoding process and the matching stage are applied.

The efficiency of the localization stage is essential to the success of the iris recognition system given the fact that error rates will increase if regions that do not belong to the iris are coded and processed [1].

This work does not have the purpose of suggesting new methods to perform the iris segmentation. The objective is to evaluate traditional methods found in literature when compressed images are used instead of images with high resolution.

An iris recognition system requires that the data related to the iris be stored for future comparison. The problem of storing the raw format of the image of the iris is that these images occupy a lot of space on disk and demand a high bandwidth for transmission.

There is the alternative of storing only the code or template generated from the characteristics of the iris, which is considerably smaller. However, this code is generated by some proprietary algorithm, which would make the system dependent on some specific supplier.

Presently, governmental organizations have demanded that biometric data be stored and recorded in the form of raw images, in order to have more negotiation freedom.

The fact that images are stored in raw format, that is, without any preprocessing, also has the advantage of allowing the data bank to take advantage of the inevitable evolutions of recognition algorithms in the future.

In this context, it is possible to see the necessity of image compression in biometry, and also the importance of knowing how much the captured image can be compressed without harming the performance of the iris recognition system.

In this work, it will be verified what happens to the efficiency of the segmentation algorithms when the images undergo severe compression. For such, the fractal compression method that utilizes quadtree partitioning and the JPEG2000 compression are used with the objective of compressing the iris images at various compression rates, and analyzing up to what point compression would be viable.

In the next section, the segmentation methods that were used in this work are presented. In section III some features of JPEG2000 compression and Fractal compression are cited. All the experimental results of the algorithms simulations are presented in section IV which are the basis for the evaluation of the methods. Finally, in section V the work is concluded.

II. IRIS SEGMENTATION METHODS

The pupil border and the external border of the iris, that together define the iris region, present a near elliptical contour. Nevertheless, the most traditional researches on iris recognition approximate them to circles with minimal loss in performance. Consequently, circle detection algorithms are usually applied to process the iris localization.

Investigating the iris localization methodologies in the literature, it is possible to identify two major strategies on which those methodologies are based. Some methods are template-based and usually involve the maximization of some equations. Other methods are boundary-based and demand the construction of an edge map for a later application of some geometric form-fitting algorithm.

In this work, two methods were evaluated, each of them representing one of the possible strategies cited.
The most traditional and widely used template-based method is the Integro-Differential Operator proposed by John Daugman [2].

The most important boundary-based methods apply the Circular Hough Transform to find circles in an edge map, which was first suggested by Wildes [3]. This localization methodology was used, with several small variations, in many works such as [1], [4], [5] and many others.

The segmentation of the iris region also includes the detection and the exclusion of the eyelids and eyelashes interferences. The method proposed by Libor Masek [1] was also evaluated when compressed images are used.

The main features of the two iris segmentation methods and the eyelids and eyelashes detection method applied are briefly explained in the following subsections.

A. Circular Hough Transform

The Circular Hough Transform (CHT) [6] was proposed by Paul Hough in 1962. This technique is able to recognize the circles present in an image and can be used to obtain the parameters that define the circle that represents the pupil border and the circle that represents the external iris border. These parameters are the radius and the coordinates of the circle center.

The first step is to convert the gray-scaled eye image into a binary edge map. The construction of the edge map is accomplished by the Canny edge detection method [7] with the incorporation of gradient information.

The Hough procedure requires the generation of a vote accumulation matrix with the number of dimensions equal to the number of parameters necessary to define the geometric form. For a circle, the accumulator will have 3 dimensions.

In the CHT, each edge pixel with coordinates \( (x, y) \) in the image space is mapped for the parameters space determining two of the parameters (for example, \( x \) and \( y \)) and finding the third one (for example, \( r \)) which resolves the circle equation \( (x-x_0)^2+(y-y_0)^2=r^2 \). As a result, the point \( (x_c, y_c, r) \) is obtained in the parameters space which represents a possible circle in the image.

At each set of parameters obtained \( (x_c, y_c, r) \), the value of the accumulator in this position \( A(x_c, y_c, r) \) is incremented, i.e., a vote is attributed to that position. When all the pixels have been processed, the highest values of the accumulator \( A \) (i.e. the position that has received the highest number of votes) will indicate the parameters of probable circles in the image.

The radius of the external border of the iris and the one of the pupil have a different average size, hence, the detection of those two circumferences is carried out separately, i.e., it is necessary to apply the whole algorithm to detect the external iris circle and then, repeat it for the detection of the pupil.

B. Integro-Differential Operator

John Daugman [2] proposed an Integro-Differential operator to locate the circular regions of the iris and the pupil. This operator is defined by the equation 1.

\[
\max(r, x_0, y_0) \left| \int G(r) \frac{\partial}{\partial r} \int_{c} \frac{I(x, y)}{2\pi r} \, ds \right|
\]  \hspace{1cm} (1)

Where \( I(x, y) \) is the image of the eye, \( r \) is the search radius, \( G(r) \) represents a Gaussian smoothing function and \( s \) is the contour of the \( r \) radius circle with the center in \( x_0 \) and \( y_0 \). The operator searches for the circular path where there is the greatest change in pixel values when there is a variation of the radius and the \( x \) and \( y \) coordinates from the center of the circle. The operator is applied interactively with the amount of smoothing being progressively reduced in order to attain precise localization.

Although the iris search results depend on the pupil search, it is not possible to assume the same concentricities of these limits. Therefore, the three parameters that define the circle of a pupil must be estimated separately from the ones that define the iris.

C. Detection of Eyelids and Eyelashes

A procedure suggested by Libor Masek [1] was used to perform the detection of the region of the iris covered by the eyelids and eyelashes. To isolate the eyelids, it was admitted that their edges could be approximated by a line segment. The first step is to find a line that corresponds to the edge of the superior eyelid and one that corresponds to the inferior eyelid. To achieve this, the Linear Hough Transform was used. A second line is then drawn horizontally intercepting the first at the edge point of the iris closest to the pupil. This procedure is done for both the superior and the inferior eyelids. The regions above the horizontal line referent to the superior eyelid and below the line referent to the inferior eyelid are excluded.

It may happen that, in some images, there is no occlusion of the iris by the eyelids. Therefore, if the maximum value in the Hough space is smaller than a predetermined threshold, no line is identified, which represents a non occlusion. Moreover, a line is only considered when it is found out of the pupil region and in the iris region.

To isolate the eyelashes a threshold determination technique is used, considering that in the group of images used the eyelashes are in general a little darker when compared to the rest of the image. Consequently, all of the pixels in the image darker than the threshold established are considered to be pixels which belong to the eyelashes and are consequently excluded.

III. COMPRESSION ALGORITHMS

Two different compression algorithms were applied to the iris images. One of them was the widely used JPEG2000 compression and the second one was chosen to be the Fractal compression that is based on different concepts.

The main reason for the utilization of the second method was to guarantee that the conclusions about the behavior of the segmentation algorithms are not dependent on the kind of compression technique that is applied.

In the next subsections, some features of those two techniques are presented.
A. JPEG2000 Compression

JPEG2000 is an image coding system that was created by the Joint Photographic Experts Group committee in 2000. It is a more powerful version of JPEG coding offering improved image quality at very high compression ratios [8]. JPEG2000 has a superior compression performance over JPEG and it is attributed to the use of Discrete Wavelet Transform (DWT) and a more sophisticated entropy encoding scheme instead of the Discrete Cosine Transform (DCT). As a result, artifacts are less visible and there is almost no blocking. Moreover, JPEG2000 decomposes the image into a multiple resolution representation in the course of its compression process allowing local areas within each image tile to be encoded using different subbands of coefficients [9].

The advantage of the JPEG2000 over JPEG in terms of image quality is more evident at very low bit rates [9] that correspond to severe compression, as studied here.

The JPEG2000 compression and decompression at various quality factors was performed using the Linux tools pamtojpeg2k and jpeg2ktopen from the JasPer JPEG2000 and Netpbm libraries.

B. Fractal Compression

Fractal compression is a technique based on the principle that real images have self similarity and that these similarities consist of redundant information, which can be eliminated. For this, several transformations are applied over all or part of an image which in turn makes each part of the image to have a convergence to a common point called the attractor [10]. This way, the images can be stored through groups of affine transformation coefficients, consequently reducing the memory utilized.

Fractal compression differs from other lossy compression methods, such as JPEG, in a number of ways. JPEG achieves compression by discarding image data that is not required for the human eye to perceive the image. The resulting data is then further compressed using a lossless method of compression. To achieve greater compression ratios, more image data must be discarded, resulting in a poorer quality image with a pixelized (blocky) appearance [11]. Fractal images are not based on a map of pixels. Once an image has been converted into fractal code its relationship to a specific resolution has been lost; it becomes resolution independent. The image can be recreated to fill any screen size without the introduction of image artifacts or loss of sharpness that occurs in pixel-based compression schemes.

In this work, a fractal compression method with quadtree partitioning [10] was implemented in Java environment. The implementation assures great processing speed of the images and wide parameter manipulation with the purpose of balancing image quality and compression rate. The coefficients of the compression algorithm were adjusted so as to obtain images with various degrees of compression.

IV. EXPERIMENTAL RESULTS

Experimental tests have been carried out utilizing the public and free UBIRIS database (Section I) [12] that contains a total of 1201 gray scale eye images with resolution 200x150. These images were captured inside a dark room in order to minimize noise factors, especially those relative to reflections, luminosity and contrast. Even so, all images present a specular reflection near or inside the pupil region, and also, some of them are poorly focused.

The JPEG2000 compression and the fractal compression method were utilized to compress the images from the UBIRIS database with the following compression rates (CR): 0.7, 0.5, 0.3 and 0.15. In this way it was possible to evaluate the efficiency of the segmentation methods when the images suffer compression from moderate rates (0.7 rate) to extremely severe compression rates (0.15 rate).

Table I shows the effect of compression on the images. In average, the original images have a size of 22000 bytes, consequently compression at rates of 0.7, 0.5, 0.3 and 0.15 produce compressed images with an average size of 15400, 11000, 6600, and 3300 bytes respectively. In relation to the original image, compression at these rates represents an average reduction factor of 1.5:1, 2:1, 3.5:1 and 6.7:1, respectively.

In the following subsections, the results obtained with each segmentation method will be presented. Next, all results will be summarized in Table II.

<table>
<thead>
<tr>
<th>CR</th>
<th>Original Size</th>
<th>Reduction factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR = 0.7</td>
<td>15.4 KB</td>
<td>1.5:1</td>
</tr>
<tr>
<td>CR = 0.5</td>
<td>11 KB</td>
<td>2:1</td>
</tr>
<tr>
<td>CR = 0.3</td>
<td>6.6 KB</td>
<td>3.5:1</td>
</tr>
<tr>
<td>CR = 0.15</td>
<td>3.3 KB</td>
<td>6.7:1</td>
</tr>
</tbody>
</table>

A. Results of the Hough Transform Application

In order to apply the Hough transform to an image, it is necessary to generate an edge map from this image first. Therefore before verifying the influence of fractal compression in the segmentation capacity of the iris through the Hough transform, it is interesting to analyze the effect of compression on the edge map that is generated.

The edge map of each original image was compared to the edge map of the corresponding image compressed at the rates of: 0.7, 0.5, 0.3 and 0.15 using JPEG2000 compression and also Fractal compression. In average, 91.3% of the pixels considered to be edge pixels in the original image were also considered edge pixels in the edge map generated from the compressed image at a rate of 0.7 bpp when JPEG2000 compression was applied and 90.5% when Fractal compression was applied. For the edge maps generated from the images compressed at rates of 0.5, 0.3 and 0.15 bpp, this
ratio was, in average of 81.1%, 78.5% and 49.8%, respectively, when JPEG2000 was used and 79.7%, 78.1% and 51.5%, respectively, when Fractal compression was used.

It can be observed that with the compression rate of 0.7 bpp, there was little variation in the edge map and as a result, from the original images that were correctly segmented, the percentage of compressed images that was also correctly segmented was 99.8% for the JPEG2000 compression and 99.5% for the Fractal compression. This shows that moderate compression practically does not interfere in the efficiency of the Hough transform.

For the compression rates of 0.5 and 0.3, the edge map varied a little more, even so the algorithm was capable of correctly segmenting, respectively, 99.4% and 98.4% of the images compressed by JPEG2000 and 99.3% and 98.5% of the images compressed by Fractal. This still represents a very acceptable efficiency.

With a compression rate of 0.15, the algorithm was capable of correctly segmenting 93.5% of the images compressed by JPEG2000 and 94.7% of the images compressed by Fractal. The reduction of the efficiency of the algorithm was probably due to the more intense variation that occurred in the edge maps.

### B. Results of the Integro-Differential Operator Application

When applying the integro-differential operator to original and compressed images it was observed that when the compression was performed with rates of 0.7 and 0.5 bpp, 100% of the original images that were correctly segmented were also properly segmented when compressed using both JPEG2000 and Fractal compression. Therefore, compression at these rates did not harm in any way the efficiency of the segmentation algorithm.

With a compression rate of 0.3 bpp, the algorithm was capable of correctly segmenting 98.3% of the images compressed by JPEG2000 and 98.6% of the images compressed by Fractal, which represent a margin of error that can be ignored in face of the benefits of compression.

When a more severe compression rate was used (0.15), 88.2% of the images compressed by JPEG2000 and 89.7% of the images compressed by Fractal were correctly segmented. In this case, it is observed that the algorithm suffered greater interference from compression and for this technique this was especially due to the reduction in contrast between the white part of the eye and the iris and between the iris and the pupil in the compressed image.

### C. Results of the Eyelids and Eyelashes Detection Method

The proposed method for the detection of eyelids and eyelashes was also applied to the original images and to compressed images with rates of 0.7, 0.5, 0.3 and 0.15 using JPEG2000 compression and Fractal compression. It was noticed that 100% of the original images that had the eyelids and eyelashes correctly detected also had them correctly detected using any of the compression rates and any of the compressing algorithms. This shows that compression, even when severe, does not harm the algorithm utilized to detect eyelids and eyelashes.

### TABLE II

<table>
<thead>
<tr>
<th>CR</th>
<th>Circular Hough Transform</th>
<th>Integro-Differential Operator</th>
<th>Eyelids/Eyelashes detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>JPEG 2000</td>
<td>0.7</td>
<td>99.8%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>99.4%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>0.3</td>
<td>98.4%</td>
<td>98.3%</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td>93.5%</td>
<td>88.2%</td>
</tr>
<tr>
<td>Fractal</td>
<td>0.7</td>
<td>99.5%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>99.3%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>0.3</td>
<td>98.5%</td>
<td>96.6%</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td>94.7%</td>
<td>89.7%</td>
</tr>
</tbody>
</table>

### V. CONCLUSIONS

Through the results obtained with the simulations that were presented in the previous section, it was possible to conclude that, in general, the most traditional boundary-based and template-based algorithms for iris segmentation continue presenting good performance even with compressed images. To validate this conclusion the images of the UBIRIS database [12] were compressed using two different compression algorithms: JPEG2000 and Fractal compression. The results presented similar characteristics in both cases.

The Hough transform algorithm showed itself to be a little more immune to severe compression rates than the integro-differential operator algorithm. For a compression rate of 0.15 bpp the first one had an efficiency of 93.5% using JPEG2000 compression and 94.7% using Fractal compression while the second had and efficiency of 88.2% for JPEG2000 compression and 89.7% for Fractal compression.

Finally, it is concluded that in a complete iris recognition system, the segmentation stage will not represent a bottleneck, that is, it will not compromise the performance of the system in case compressed images are used.

The next work to be suggested is to perform a research of how compression will interfere in the other stages of processing, especially in the system's ability to recognize individuals precisely.

### ACKNOWLEDGMENTS

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### REFERENCES


