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An Effective Segmentation Technique for Noisy Iris Images

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ABSTRACT

In today's sensitive environment, for personal authentication, iris recognition is the most attentive technique among the various biometric technologies. In iris recognition systems, when capturing an iris image under unconstrained conditions and without user cooperation, the image quality can be highly degraded by poor focus, off-angle view, motion blur, specular reflection (SR), and other artifacts. The noisy iris images increase the intra-individual variations, thus markedly degrading recognition accuracy. To overcome these problems, we propose a new segmentation technique to handle iris images were captured on less constrained conditions. This technique reduces the error percentage while there are types of noise, such as iris obstructions and specular reflection. The proposed technique starts by determining the expected region of iris using K-means clustering algorithm, then circular Hough transform is used to localize iris boundary. After that, some other technique will be applied to detect and isolate noise regions.

Keywords: Iris Recognition, Iris Segmentation, Specular Reflection, Iris Obstructions.

1. INTRODUCTION:

Automated personal authentication has always been an attractive goal in computer vision. With an increasing emphasis on security, the need for automated personal identification system based on biometrics has increased. Due to various cyber-threats, there is a need for identification systems identify humans without depending on what person possesses or what person remembers. Among the various biometrics traits (like fingerprints, facial features, retina, iris, voice, gait, fingerprint, palm-prints, handwritten signatures and hand geometry), Iris recognition has attracted a lot of attention because it has various advantageous factors like greater speed, simplicity and accuracy compared to other biometric traits. Since the concept of automated iris recognition was proposed in 1987 [22], many researchers worked in this spot and proposed many powerful algorithms such as Texture-variations based approaches, Phase-based methods [15] , [29] , [16], Zero-Crossing representation [35], Texture Analysis [38] , [4], and Intensity Variations [20]. But, the algorithms developed by Daugman are the most relevant algorithms and widely used in current real applications. This research paper aims to propose an effective segmentation technique able to deal with highly noisy iris images capturing on less constrained conditions and non-ideal environments. In this proposed technique, K-Means Clustering, Canny Edge Detection, Circular Hough Transform, and some other algorithms are used to deal with expected types of noise such as iris obstructions & specular reflection and reduces the error percentage.

2. IRIS RECOGNITION METHODS:

Mostly iris recognition systems approximately share the Iris Segmentation, Iris Normalization, Feature Extraction, and Feature Comparison stages (Figure 1). The most popular iris recognition methods are as follows:

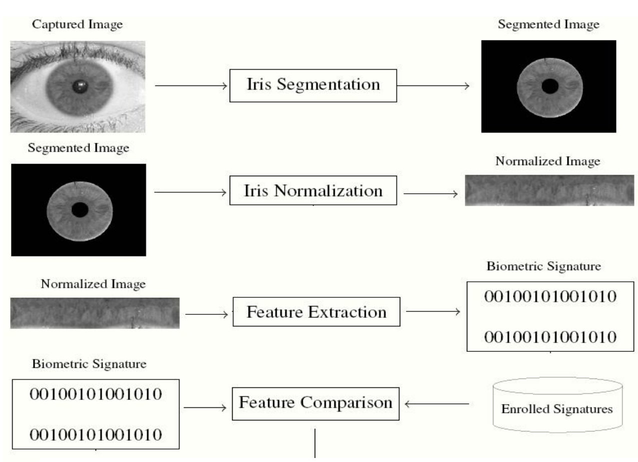

Figure 1 Stages of Iris Recognition Systems

2.1 Daugman's Method

Daugman's 2004 [8] described that image acquisition should use near-infrared illumination so that the illumination could be controlled. Near-infrared illumination also helps reveal the detailed structure of heavily pigmented (dark) irises. The next step is localizing the iris from image. Daugman proposed an Integro-Differential operator for detecting the iris boundary by searching the parameter space. Due to the distance from the camera, illumination variations and angle of the image capturing, the size of multiple copies of the images of an iris is not same. To normalize the segmented iris, Daugman proposed the rubber sheet model. In this model, the iris is remapped from raw Cartesian Coordinates (x,y) to the Real Polar Coordinates (r,θ), where r is in the unit interval [0,1] and θ is an angle in [0,2Π]. To extract the features from the normalized iris, Daugman applied a two dimensional texture filter called Gabor filter [7] to an image of the iris and extracted a representation of the texture, called the iris code. To compare two iris templates or signatures, Daugman used Hamming distance. Here, given two binary sets, *A* and *B*, with *N bits* each: where $A = \{a_1,..., a_N\}$ and $B = \{b_1, ..., b_N\}$, the Hamming distance is:

$$HD(A,B) = \frac{1}{N} * \sum_{i=1}^{N} a_i \otimes b_i$$

Where $\otimes$ is the logical XOR operation. Thus, for two completely equal signatures the value of the Hamming distance will be 0, and in completely different signatures, the value of the Hamming distance will be 1.

2.2 Wildes' Method

Wildes [31] described an iris biometrics system uses different techniques from that of Daugman. To accomplish iris segmentation Wildes used a gradient based binary edge-map construction followed by circular Hough transform. This method became the most common method in iris segmentation, many researchers [13], [17], [36], [24] later proposed new algorithms depend on this method. Wildes applied a Laplacian of Gaussian filter at multiple scales to produce a template and compute the normalized correlation as a similarity measure after normalizing the segmented iris. He used an image registration technique to compensate scaling and rotation then an isotropic band-pass decomposition is proposed, derived from application of Laplacian of Gaussian filters to the image data. In the Comparison stage a procedure based on the normalized correlation between both iris signatures is used. Although Daugman‘s system is simpler than Wildes‘ system, Wildes‘ system has a less-intrusive light source designed to eliminate specular reflections. Wildes‘ approach is expected to be more stable to noise perturbations, it makes less use of available data, due to binary edge abstraction, and therefore might be less sensitive to some details. Also, Wilde's approach encompassed eyelid detection and localization [21].

2.3 Key Local Variations Method

Li Ma, Tieniu Tan, Yunhong Wang, and Dexin Zhang proposed a new algorithm for iris recognition by characterizing key local variations. The basic idea is that local sharp variation points, denoting the appearing or vanishing of an important image structure, are utilized to represent the characteristics of the iris. First, the background in the iris image is removed by localizing the iris by roughly determine the iris region in the original image, and then use edge detection and Hough transform to exactly compute the parameters of the two circles in the determined region. In order to achieve invariance to translation and scale, the annular iris region is normalized to a rectangular block of a fixed size using the methods in [38], [23]. Then lighting correction and image enhancement is applied to handle the low contrast and non-uniform brightness caused by the position of light sources. In feature extraction stage they constructed a set of 1-D intensity signals containing the main intensity variations of the original iris for subsequent feature extraction. Using wavelet analysis, they recorded the position of local sharp variation points in each intensity signal as features. Directly matching a pair of position sequences is also very time-consuming. So, they adopted a fast matching scheme based on the exclusive OR operation to solve this problem [25]. Figure 2 shows the stages of segmentation and normalization.

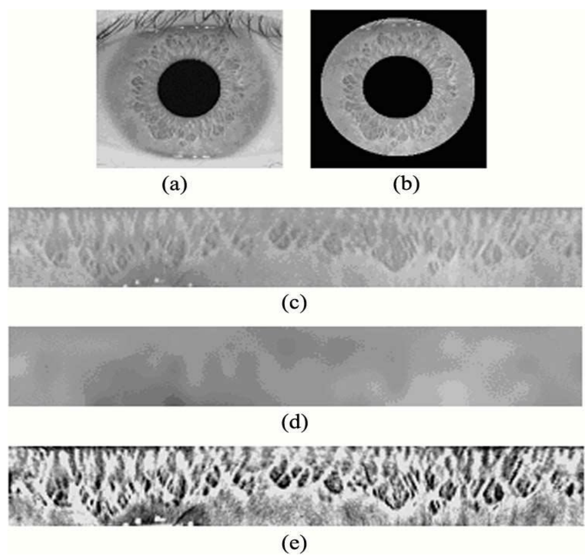

Figure 2 Iris Image Preprocessing (a) original image (b) localized image (c) normalized image (d) estimated local average intensity (e) enhanced image [25]

3. IRIS SEGMENTATION METHODS:

For iris segmentation, many researchers have contributed their efforts & used different techniques to increase the performance. Iris segmentation techniques can be classified into two categories:

- Classification according to the region of starting.
- Classification according to the operators or techniques used to describe the shapes in all eyes.

Further, there are three categories of researchers depending on where do they start the segmentation.

- The first category of researchers starts the segmentation from pupil [3], [30] because it is the darkest region in the image. Based on this, pupil is localized and the pupillary boundary of iris is fixed, then the iris is determined using different techniques. Finally, noises are detected and isolated from the iris region.

- In the second category, [5] the process starts from the sclera region because the sclera part is found to be less saturated (white) than other parts of the images especially for images containing heavily pigmented (dark) irises, or images affected by noise. After determining the sclera region, the iris is detected using any type of operators. Finally, the pupil and noises are detected and isolated from iris region.
- The third category [27], [10] of researchers directly search the iris region using edge operators or apply clustering algorithms to extract texture features of the iris.

Further, there are two common approaches to localize the iris region according to the used techniques:

- The first technique [37], [26] is applying type of edge detection followed by Hough transform or one of its derivatives to detect the shape of iris and pupil, sometimes a final stage is applied to correct the shape of iris or pupil.
- The second type [3], [19], [33], [34] uses different types of operators to detect the edges of iris like Daugman's [32] Integro-Differential operator or Camus and Wildes operator and use the same operator or another one to remove the pupil region.

The most famous and robust iris segmentation methods are as follows:

3.1 Daugman's Method

Daugman's method [1] is the most cited in the iris segmentation literature. Iridian Technologies turned it into the basis of 99.5% of the commercial iris recognition systems. It was proposed in 1993 and was the first method effectively implemented in a working biometric system. Daugman assumes both pupil and iris are localized with circular form and applies the following operator

$$\max_{r,x0,y0}\left|G_\sigma(r)*\frac{\delta}{\delta r}\oint_{r,x0,y0}\frac{I(x,y)}{2\pi r}ds\right|$$

Here, $I(x,y)$ is an image; ds is circular arc of radius r; $(x0,y0)$ are Center coordinates; Symbol * denotes convolution; and $G_\sigma(r)$ is a smoothing function. This process works very effective on images with enough separability between iris, pupil and sclera intensity values. But the major disadvantage of this method is that it frequently fails when the images do not have sufficient intensity separability, specially between the iris and the sclera regions and also fails where there are exist types of noise in the eye image, such as reflections. So, it works excellent only on images picked at Near Infrared camera and in ideal imaging conditions.

3.2 Camus and Wildes' Method

Camus and Wildes [8] presented a robust, real-time algorithm for localizing the iris and pupil boundaries of an eye in a close-up image. It uses a multi-resolution approach to detect the boundary contours of interest quickly and reliably, even in cases of very low contrast, specular reflections and oblique views. This algorithm used for both the pupil and iris boundaries a component-goodness-of-fit metric for candidate boundary parameters being considered with respect to a given center for the polar coordinate system. The component-goodness-of-fit is defined as

$$C=\sum_{\theta=1}^{n}\left((n-1)\|g_{\theta,r}\|-\sum_{\phi=\theta+1}^{n}\left(\|g_{\theta,r}-g_{\phi,r}\|\right)-\frac{I_{\theta,r}}{n}\right)$$

where n is the total number of directions and $I_{\theta,r}$ and $g_{\theta,r}$ are respectively the image intensity and derivatives with respect to the radius in the polar coordinate system. This method is highly accurate with images whose pupil and iris intensities are well separated from the sclera ones and with images that contain no significant noise regions, such as reflections. Otherwise, when dealing with noisy data, the algorithm's accuracy significantly deteriorates [9].

3.3 Wildes' Method

An automatic segmentation algorithm based on the circular Hough transform is employed by Wildes [31]. It performed its contour fitting in two steps. First, the image intensity information is converted into a binary edge-map. Second, the edge points vote to instantiate particular contour parameter values. The voting procedure is realized via Hough transforms [18], [28]. The parameter with largest number of votes (edge points) is a reasonable choice to represent the contour of interest. The second step recently called circular Hough transform. There are a number of problems with the Hough transform method. It requires threshold values to be chosen for edge detection and the Hough transform is computationally intensive due to its Brute-force approach which may not be suitable for real time applications.

3.4 Proenca Method

Proenca [11] developed an algorithm to segment degraded images acquired in the visible wavelength. The algorithm is divided into two parts: detecting noise-free iris regions and parameterizing the iris shape. The initial phase is further subdivided into two processes: detecting the sclera and detecting the iris. The key insight is that the sclera is the most easily distinguishable region in non-ideal images. Next, he exploited the mandatory adjacency of the sclera and the iris to detect noise-free iris regions. He stressed that the whole process comprised three tasks that are typically separated in the literature: iris detection, segmentation, and detection of noisy (occluded) regions. The final part of the method is to parameterize the detected iris region. At last the small classification inaccuracies near iris borders handled using a constrained polynomial fitting method that is both fast and able to adjust shapes with an arbitrary degree of freedom, which naturally compensates for these inaccuracies. Proenca method is very accurate with noisy images that taken in visible wavelength, but since he depend on sclera on determining the region of iris, the algorithm may fails when the sclera covered with dark colors caused by bad image picked environments or eye diseases.

4. TEXCZVCZXSFCHNIQUESFDSAFDSS USED IN PROPOSED ALGORITHM:

In this section, basic concepts related to some used techniques in the proposed algorithms are introduced. First, overview of the K-means clustering algorithms is performed. After that the circular Hough transform and Canny edge detection are explained. Finally the morphological operations is described.

4.1 Image K-means Clustering

The K-means algorithm is an iterative technique that is used to partition an image into *k* clusters by assigning each point to the cluster whose center or centroid is nearest. The basic K-means algorithm we used is:
Step-1. Compute the Intensity distribution (also called the histogram) of the intensities.
Step-2. Initialize the centroids with *k* random intensities.
Step-3. Repeat the following steps until the cluster labels of the image does not change anymore.
Step-4. Cluster the points based on distance of their intensities from the centroid intensities.

$$c^{(i)} := \arg\min_j \left\| x^{(i)} - \mu_j \right\|^2$$

Step-5. Compute the new centroid for each of the clusters.

$$\mu_i := \frac{\sum_{i=1}^{m} 1\{c_{(i)} = j\} x^{(i)}}{\sum_{i=1}^{m} 1\{c_{(i)} = j\}}$$

Here, i iterates over all the intensities; j iterates over all the centroids; and μ_i is the centroids intensities.

4.2 Circular Hough Transform

The Hough transform [6] is a standard computer vision algorithm that can be used to determine the parameters of simple geometric objects, such as lines and circles, present in an image. It can be described as a transformation of a point in the x, y-plane to the parameter space. The parameter space is defined according to the shape of the object of interest. The circle is actually simple to represent in parameter space, compared to other shapes, since the parameters of the circle can be directly transfer to the parameter space. The equation of a circle is

$$r^2 = (x-a)^2 + (y-b)^2$$

Here, r is the radius; and a & b are the center of the circle in the x and y direction respectively. The parametric representation of the circle is

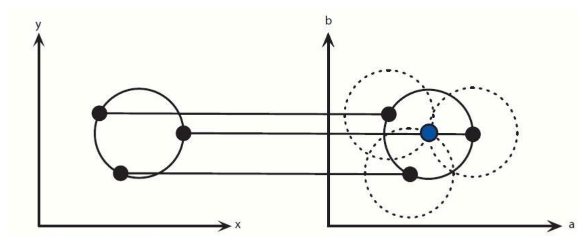

Figure 3 A circular Hough transform from the x, y-space (left) to the parameter space (right), this example is for a constant radius

$$x = a + r\cos(\theta)$$
$$y = b + r\sin(\theta)$$

The circular Hough transform can be employed to deduce the radius and centre coordinates of the pupil and iris regions. It works as follow, at each edge point result from previous edge detection step we draw a circle with center in the point with the desired radius. This circle is drawn in the parameter space. Figure 3 shows this process.

4.3 Canny Edge Detection

There are many methods for edge detection, but one of the most optimal edge detection methods is Canny edge detection [12]. It receives a greyscale image and outputs a binary map correspondent to the identified edges. It starts by a blur operation followed by the construction of a gradient map for each image pixel. A non-maximal suppression stage sets the value of 0 to all the pixels of the gradient map that have neighbours with higher gradient values. Further, the hysteresis process uses two predefined values to classify some pixels as edge or non-edge. Finally, edges are recursively extended to those pixels that are neighbours of other edges and with gradient amplitude higher than a lower threshold. The Canny edge detection receives the following arguments: Upper threshold, Lower threshold, Sigma of the Gaussian kernel, Vertical edges weight, Horizontal edges weight and Scaling factor. These arguments are determined according to the applications and environments that use the Canny edge detection.

4.4 Morphological Operations

The morphological processing refers to certain operations where an object hits a structuring element and is reduced to a more revealing shape. The aim is to transform the signal into a simpler one by removing irrelevant information and can be applied to binary and gray level signals [2]. Most morphological operations can be defined in terms of two basic operations: Erosion and Dilation. Erosion and dilation are two morphological operations that are very useful in processing binary images. Erosion and dilation, allow groupings of *ones*, represented by white pixels, to be enlarged or shrunk to produce resulting images that either fill grouping gaps or remove small groupings of *ones* as necessary. In our proposed iris segmentation algorithm, the aim of using Morphological operations is to eliminate eventual noisy data and smooth the information with the purpose of facilitating the segmentation.

5. Proposed Iris Segmentation Algorithm:

In this paper, we propose a new segmentation algorithm to handle iris images were captured on less constrained conditions. This algorithm reduces the error percentage while there are types of noise exist, such as iris obstructions and specular reflection. The segmentation stage is important because it is the basis of all further operations, such as normalization and encoding. As mentioned, there are many iris segmentation algorithms were proposed before, and gave an excellent results when iris images picked at Near Infrared camera and in ideal imaging conditions. The accuracy of current segmentation algorithms significantly decreases when dealing with noisy iris images taken in visible wavelength under far from ideal imaging conditions, available with CASIA-IrisV4 database. The proposed algorithm starts by determining the expected region of iris using K-means clustering algorithm, then circular Hough transform is used to localize iris boundary, after that some algorithms are proposed to detect and isolate noise regions. Figure 4 shows the steps of our proposed iris segmentation algorithm. The proposed iris segmentation technique avoid starting from the pupil, because the pupil is not always the darkest region in the eye in the noisy images that were taken in a visible wavelength (due to some factors like shadows, specular reflections and highlights). Figure 5 shows some noisy eye images, where the pupil is affected by these factors.

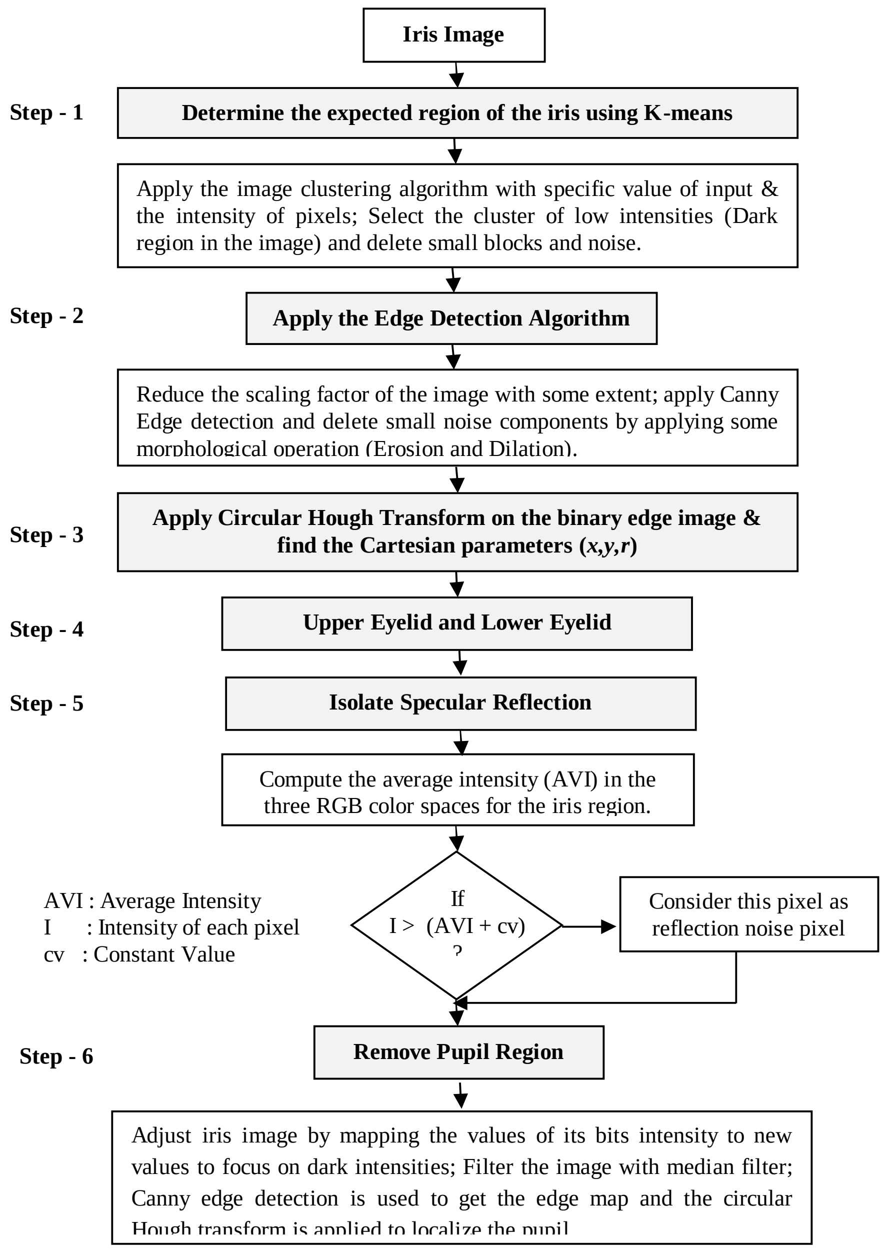

Figure 4 Steps of Proposed Iris Segmentation Technique

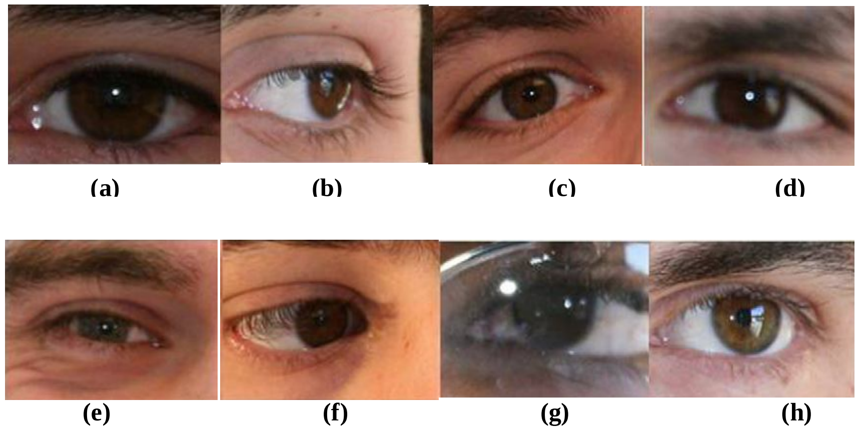

Figure 5 The Noisy Iris Images (NICE.II training dataset)
(a) Low illumination. (b) Off-angle.
(c) Rotation. (d) Blurring.
(e) Occlusion by eyelids.
(f) Occlusion by eyelashes.
(g) Noises by glasses.
(h) Occlusion by ghost region.

4. CONCLUSION:

Noisy Iris Recognition technology provides a practically & significantly feasible technique for overcoming the performance and user acceptability obstacles to the widespread adoption of biometric systems. Much research effort around the world is being applied for expanding the accuracy and capabilities of this biometric domain, with a consequent broadening of its application in the near future. This research paper proposed an effective iris segmentation technique for noisy iris images and reduces the error percentage.

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