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A Robust Iris Localization and Texture Extraction Scheme for Iris Authentication Systems

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ABSTRACT

Biometrics systems accurately identify and distinguish individuals based on their characteristics. Due to the high accuracy and stability, iris has been widely used in the authentication process of authorized persons. One of the most important processes in developing an iris recognition system is iris segmentation since it has a substantial impact on the accuracy of iris matching. Although there are several influencing factors such as overlapping eyelashes, eyelids, and lighting, it must be the area of the iris that is precisely defined. Several attempts towards robust iris localization and segmentation have been made in light of these challenges. A robust iris localization method based on a circular Hough transform and an active contour model was presented in this study. The precisely extracted iris region, and its distinctive characteristics, are extracted using the Gray Level Co-occurrence matrix (GLCM) method, depending on different types of images, some of which were captured using near-infrared (NIR) under specific capture conditions. The other part of the pictures was taken with normal visible wavelength (VW). The co-occurrence matrix is used to estimate the Homogeneity, Energy, Contrast, Correlation, and Entropy collection of second-order statistical features. Experimental results on 100 images from CASIA v1, IITDv1, and UBIRIS v1 iris images databases show that our method achieves high accuracy and small time.

1. Introduction

One of the most popular techniques for identifying and distinguishing people based on their biometric features is Iris recognition (IR). The iris recognition technology points to each person's unique iris code to maintain a high level of security. In comparison to other biometric technologies, the iris recognition system is one of the most reliable people identification systems, as well as one of the most recent. The first automatic iris detection technology was devised and published by John Daugman in 1994 [1,2].

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Iris recognition technology is employed in a wide range of applications .The main applications of this technology are passport replacement (automatic transfer of border), access control for restricted areas, database access, machine logins, and other government programs [3,4].

The human iris has many features that can be taken advantage of and exploited by designing people's recognition systems accurately, unlike the rest of other biometrics [5]. The iris is fixed and does not change over time, so iris recognition systems do not need to update the data stored in their databases, which makes the systems reliable over time. Iris Uniqueness where each individual is characterized by its iris pattern and is not similar to any other individual. The shape of the iris pattern is unique, which means that each person has a distinctive iris code, as even twins do not have the same iris code. The evolution of distinctive iris patterns is random and not linked to genetics. Only the iris color is affected by genetics [5].

One of the most important stages in the iris recognition system is the stage in which the part of the iris is determined without the rest of the other parts of the eye because of its texture and special shape for each user. The segmentation process includes defining and deducting the part of the iris from the rest of the other parts of the eye. Therefore, the boundaries of the iris with the pupil are determined as the inner border rather than the form of a circle, and the limit of the iris with the cornea is determined as the outer border. These parts must be carefully selected, and other unwanted parts must be removed as they greatly affect the overall performance of the system.

This study aims to find a specific method that works to identify and isolate the iris of the eye accurately. After the iris is identified and isolated, unwanted noises such as eyelids and eyelashes are removed, and specific characteristics and values are extracted using the second-order statistical method Gray Level Co-occurrence Matrix (GLCM) to extract appropriate iris texture features. For proficiency testing, the proposed system is evaluated based on False Acceptance Ratio (FAR) and False Rejection Ratio (FRR). The proposed iris determination method with iris characterization extracting method based on GLCM was tested on two types of images, one based on visible light VW, such as images in UBIRIS. In contrast, images taken based on NIR are found in CASIA and IITD.

The manuscript's structure is as follows: Section 2 provides the proposed methodology, Section 3 presents the findings, and Section 4 summarizes the conclusions.

2. Proposed Methodology

Due to its obvious particular properties, the iris is a good choice for using its properties as a biometric for classifying individuals. The distinctive and unique characteristics of the iris are extracted from the eye image and placed in the database as a template using image processing techniques [6]. The essential stages of an iris recognition system are summarized in Figure 1 [7-8].

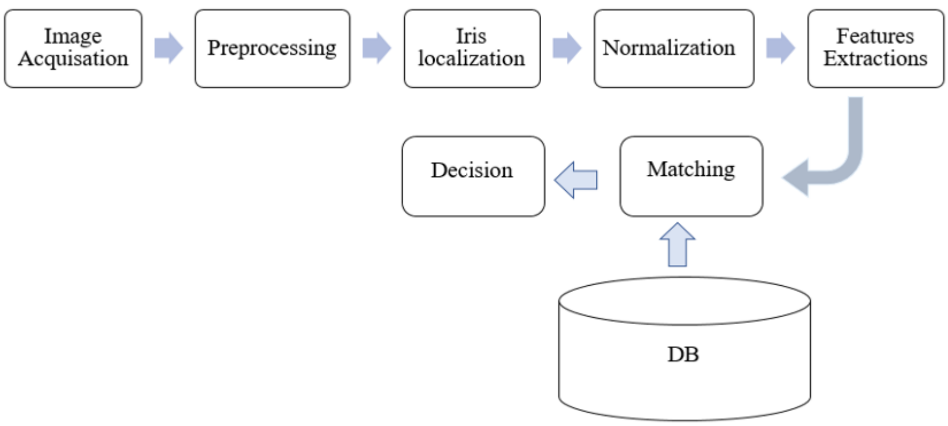
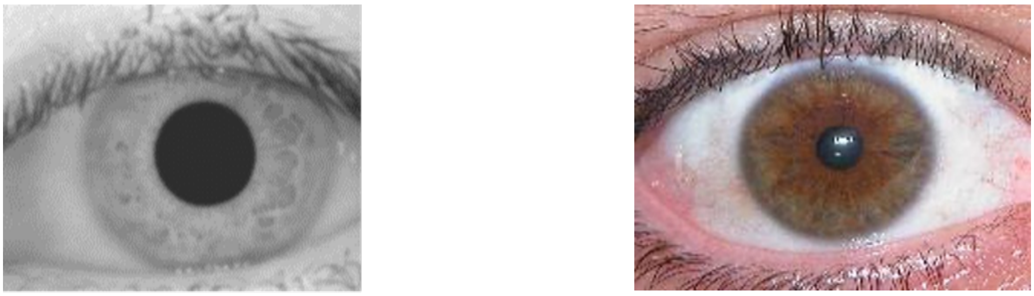


Fig. 1. The general structure of the Iris recognition system

2.1 Image Acquisition

The first stage of the system involves collecting input images from different sources. Image quality affects the overall performance of iris recognition systems. Obtaining high-quality iris images takes work, as the iris has a diameter of about 11 mm, which is a relatively small part of the face. Images of the iris are captured either using near-infrared (NIR) or wavelength light (VW) [9].

The majority of commercial iris capture devices use near-infrared (NIR). The illumination source emits light with a wavelength of 700-900 nm. Even with highly pigmented irises (black eyes), the structure of iris patterns is detectable at those wavelengths, in contrast to visible wavelength light, and light reflection is considerably reduced. Figure 2 depicts an example of a near-infrared iris picture and visible light [10].



(a) NIR image (b) Visible wavelength image

Fig. 2. An example of an eye obtained with NIR and VW lighting [11-12]

Images of the iris taken in near-infrared illumination give better results compared to visible-wavelength (VW) light sources for several reasons, including non-intrusion and the elimination of blinking and pupil movement (constriction). Another benefit is increased resistance to light pollution and reflections. As for visible wavelength(VW) is easy to use, uncomplicated, and convenient for the user, especially in multi-biometric systems such as the combination with facial recognition, which also works under VW lighting but at the expense of the quality of the captured image [3].

Images from CASIA v1, ITTD v1, and UBIRIS v1 were used in this project. NIR imaging datasets CASIA v1 and ITTD v1 exist, while VW noisy image datasets ITTD v1 exist.

2.2 Image Preprocessing

The preprocessing processes used in the Iris Identification System generally refer to all the processes and steps that are used to improve the image to extract clear, accurate, and error-free characteristics. It includes a variety of different processes and methods that differ according to the system used, the quality of the images, and the characteristics to be retrieved [13], such as the process of segmenting images and identifying shapes within images. And image enhancement techniques (to remove unwanted pixels or improve other image features), Image binarization by using a specific threshold and edge detection methods [5].

Iris segmentation is critical for accurate person recognition using iris patterns. The iris segmentation module defines the effective iris portion of the eye image. In this stage of the system, the boundaries of the iris with the sclera and the boundaries of the iris with the pupil are defined to extract their characteristics. The success of the iris determination process depends entirely on the quality of the images taken. Occlusions (hair, eyelashes, blink, etc.), incorrect illumination (light transitions, reflections, etc.), blur (out-of-focus, motion), off-gaze, distortion, pupil dilation, camera diffusion, variation in contrast, luminosity, and insufficient resolution are all factors that affect iris localization and segmentation. Despite the accuracy and efficiency of many iris identification algorithms, surrounding variables such as eyelids and eyelashes cover a large portion of the iris; this has an impact on the segmentation process' accuracy and, as a result, the recognition system's overall performance [14].

2.3 Iris Localization

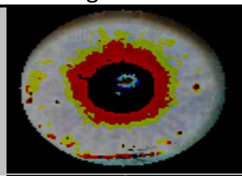
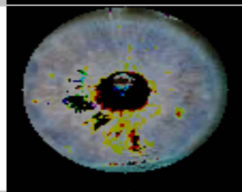
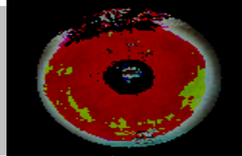
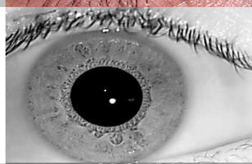
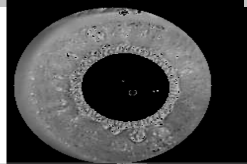
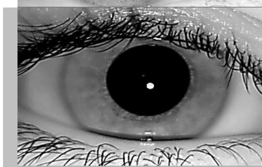
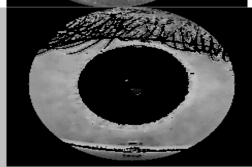
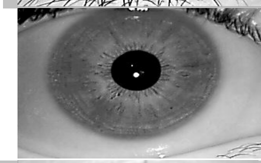
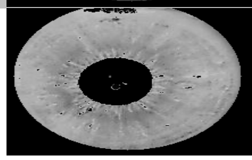
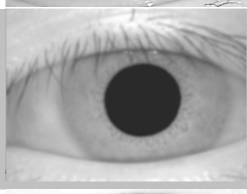
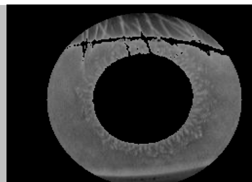
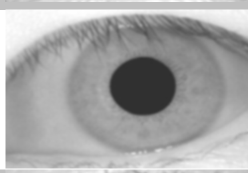
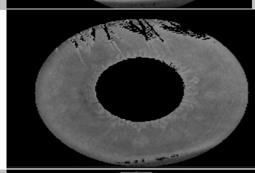
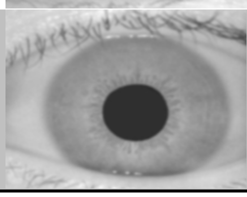
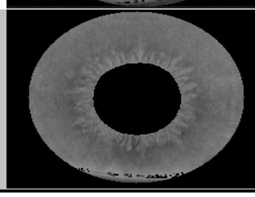
After the image is pre-processed, it is ready for the next step, which is locating the iris segment, which is the important area within the image. The technique of locating related parts within an image based on desired characteristics is known as image segmentation. There are two distinct boundaries between the iris and the pupil and another between the iris and the sclera that must be recognized, in addition to the isolation of unnecessary objects such as eyelashes, eyelids, light reflection, or any other noise. Additionally, specular reflections within the iris region might disrupt the iris pattern. To separate and exclude these artifacts, as well as define the circular iris region, the proposed system performs multiple steps. The iris segmentation procedure is divided into two steps: first, rough localization of the iris region using the Circular Hough transform [15-16], second, these circles are employed to create an active contour [17]. The Hough circular transformation is being used to determine the radius and center of the pupil and the iris portions. Recognizing the circular objects in an image with CHT involves multiple stages. This method first implements canny edge detection. Then, the transformation is calculated at each location in the image area by drawing circles of suitable radius. Models of active contours have been used to enhance the iris and pupil boundary detected from CHT in eye images. Each vertex is moved between time t and t + 1 by Eq. (1) and is used to calculate total energy (cost) [4].

$$\mathrm{Vi}(t+1) = \mathrm{Vi}(t) + \mathrm{Fi}(t) + \mathrm{Gi}(t)) \tag{1}$$

where Fi is the internal force, Gi is the external force, and Vi is the position of vertex i.

Internal energy ensures that the contour of particular known shapes, such as circles, triangles, rectangles, etc., is continuous and smooth. It controls the elasticity and smoothness [7]. Meanwhile, external energy (“image” energy) moves the contour toward the closest image edge. In precise pupil identification, the contour changes in a circular shape corresponding to the inner border of the iris. External forces depend on edge information [8]. These methods exhibited an improvement over the classic iris segmentation methods. Eyelids and eyelashes have been removed from the iris region by defining a particular threshold for each of them. Thresholding is the way of transforming a grayscale image to a black-and-white image by converting just the pixels with values greater than a particular threshold to white and the other pixels to black, as seen in Table 1.

Table 1
Original and cropped Iris from the dataset

Dataset	Original Image	Iris Image
UBIRIS v1		
		
		
IITD v1		
		
		
CASIA v1		
		
		

2.4 Iris Normalization

The conversion of the iris region from circular to rectangular with fixed dimensions is known as normalization. One of the most often used algorithms is the Daugman Rubber Sheet Model. The Daugman model converts all points in the iris to the polar coordinates (r, θ) where r is within the period [0, 1] and θ is within the period [0,2μ], as shown in Figure 3 [18]. Because the size of the iris changes with the change in the amount of light entering it, it expands as the amount of entering light increases and becomes smaller as it becomes less. Therefore, when comparing, these differences must be eliminated by using normalization to obtain the same results in different conditions [9]. In Eq. (2), the normalization mapping is illustrated as follows [19-20]:

$$I(x(r,\theta), y(r,\theta)) \rightarrow I(r,\theta) \quad (2)$$

where:
I(r, θ): is the normalized iris image.
I(x, y): is the circular iris image.
$x = rcos(\theta)$
$y = rsin(\theta)$
θ: belongs to the interval of [0, 2π]

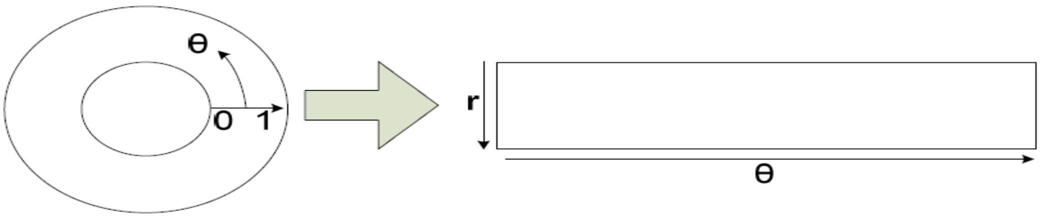


Fig. 3. The rubber sheet model of Daugman

2.5 Iris Features Extraction by GLCM

In this stage of the proposed system, the characteristics of the iris part are identified, extracted, and converted into values that are easy to store in the system database for later retrieval and comparison. So, it is the most critical step of a recognition system [20]. During matching, the feature vector will be used to compare the test image to the other feature vectors contained in the database. The most distinct elements of the iris pattern must be retrieved to distinguish individuals accurately. Only important features must be retrieved in order to be encoded in the biometric templates that can be compared. GLCM is one of the most commonly used second-order statistical methods that estimate the properties of two or more pixel values occurring in particular areas that are almost equivalent to one another. GLCM may be widely used as an iris texture examination strategy. GLCM is employed in a wide range of applications, including remote sensing, fabric defect identification, Earth data processing, soil moisture, etc.[22]. The GLCM method is based on calculating the frequency of the value of each pixel I with another pixel J at each (I, J) point in the occurrence matrix within a specified distance d and a specified angle $\boldsymbol{\theta}$ [23]. When computing GLCM from an input image, the distance "d" and the orientation angle " $\boldsymbol{\theta}$ " are the most significant elements to consider. Figure 4 (a) shows an input image with a dimension of 4*4, the GLCM of the input image is shown in Figure 4 (b), and the normalized form is shown in Figure 4 (c). Normalization can be done by dividing each occurrence pair by the total number of occurrence pairs, as in Eq. (3) below [22]. The purpose of normalization is to make the features independent of the size of the image.

$$N[i,j] = \frac{P[i,j]}{\sum\sum p[i,j]} \quad (3)$$

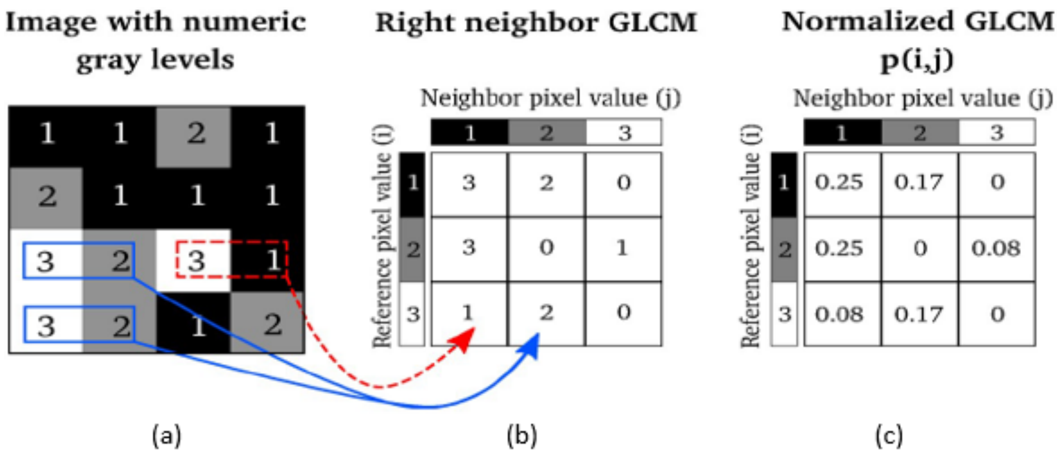


Fig. 4. Figure (a) 4 × 4 dimension input image, (b) GLCM gray level matrix d = 1 and θ = 00, (c) Normalized GLCM matrix

Many of the characteristics of the iris of the eye can be drawn as follows [24-27]:

i. Contrast : Contrast shows the difference in color values for each pixel. The contrast is given by Eq. (4):

$$\text{Contrast} = \sum_i \sum_j (i-j)^2 N_d(I,j) \tag{4}$$

where I,j represent the columns and rows in the occurrence matrix while $N_d(I,j)$ represents the frequency of each given pixel within the d dimension and angle θ in the image.

ii. Energy: Represents the number of repeated pairs in the specified segment. If the number of repeated pairs is high, the energy is high, is given by according to Eq. (5):

$$\text{Energy} = \sum_i \sum_j N_d^2(I,j) \tag{5}$$

iii. Entropy: It expresses the amount of randomness and is calculated based on the Eq. (6):

$$\text{Entropy} = -\sum_i \sum_j N_d(i,j) \log_2 N_d(i,j) \tag{6}$$

iv. Homogeneity: This feature shows local homogeneity and is high if the affinity pixel values are similar and calculated according to Eq. (7):

$$\text{Homogenetiy} = \sum_i \sum_j \frac{N_d(I,j)}{1+|i-j|} \tag{7}$$

v. Correlation: This feature shows how closely each pixel is present with another pixel in the selected segment. It is calculated according to the Eq. (8):

$$\text{Correlation} = \frac{\sum_i \sum_j (1-\mu_i)(j-\mu_j) N_d(I,j)}{\sigma_i \sigma_j} \tag{8}$$

where μ_i, μ_j Are the means and $\sigma_i \sigma_j$ are the standard deviation of the row and column.

vi. Dissimilarity: dissimilarity is quite similar to Contrast. When the gray levels of nearby and central pixels are at high levels, dissimilarity reaches its greatest value, as Eq. (9):

$$\text{Dissimilarity} = \sum_{i} \sum_{j} (i - j) N_d(i, j) \tag{9}$$

2.6 Matching and Recognition

To carry out the process of matching and comparing a person trying to enter the system with other people whose data is stored in the system database, a measure of similarity or distance is required. This scale must give close or identical results when using a template belonging to the same person and gives different values when using templates belonging to different people, taking into account the changes that occur during the process of taking pictures. The Euclidean distance is used to make the appropriate decision (ED), as shown in Eq. (10) [9].

$$ED = \sqrt{\sum (VT^{\,2} - VC^{\,2})} \tag{10}$$

Where:
VT: enrolled templates
VC: registered templates

3. Results and Discussion

The biometric verification system makes two types of errors: false matches and false non-matches. When the system incorrectly displays two samples from different users as samples from the same user, a false match (FAR) occurs. False mismatch occurs when two samples from the same user are misclassified as samples from different users (FRR). The results obtained from the proposed system were made after conducting several tests and using a set of different images taken from IITD v1, CASIA v1, and UBIRIS v1. One hundred users were tested from each database. For each user, six different images were utilized, one for experimentation and the remaining for instruction.

Table 2 shows the results of the proposed system's tests. The recognition rate is the fraction of true acceptance attempts that can also be determined (1- FRR).

Table 2
Diverse algorithms and recognition rates

Database	FAR	FRR	Time in Ms.	Recognition Rate
CASIA v1	0.0	1.7	0.0312	98.3
ITTD v1	0.0	1.5	0.07814	98.5
UBIRIS v1	0.0	17.0	0.06249	83.0

3.1 Comparison with Existing Algorithms

Table 3 presents a comparison of the system used with other existing systems

Table 3
Various algorithms and accuracy

No. of Reference	Methods for Extracting Features	Accuracy
[28]	Gabor filter	100%
[29]	LBP	99.2%

Table 3 (*continued*)

No. of Reference	Methods for Extracting Features	Accuracy
[30]	Gabor wavelet	99%
[31]	CNN	96.38%
[32]	Wavelet packet	93%
[33]	SIFT	90%
[34]	Contourlet transform	94.2%
[35]	SURF	97.32%
[36]	Haar wavelet	98.45%
[37]	OBTC	98.8%
[38]	LPCC	96.8%
[39]	EBHXEP	98%
[40]	Directionlets	97.4%
The proposed	GLCM	98.5%

The process of locating the iris with the proposed system based on the integration of two CHT methods with Active Contour succeeded in locating the iris with high efficiency and in a relatively short time. The next stage that has a substantial impact on the system's performance is the extraction of iris features using the GLCM approach. In general, the proposed system was evaluated using FAR, FRR, and GAR. The false acceptance rate has the highest priority when used in security systems where the priority is not to allow intruders to enter, even if this leads to tightening procedures for some authorized users, this feature is clearly shown in the proposed system. As for the false rejection rate, the proposed system gave a high rate compared to the pre-existing systems, as shown in Table 3.

4. Conclusions

This work suggests using the iris as an effective biometric to identify the authorized persons in the different systems. Because of the difficulty of identifying and extracting the iris from the whole eye, a new method was used to determine only the part of the iris and retrieve it based on the combination of two CHT methods with Active contour. Image quality greatly affects the performance. If the captured image contains noise, as we noticed in images captured using visible light, as found in UBIRIS v1, but in images captured using NIR, as in IITD v1 and CASIA v1, the system performance is better. The GLCM method was used to extract the characteristics of the extracted part effectively from the iris of the eye.

Various iris attributes can be analyzed for future work, which can help to increase system efficiency and be compared against other databases to improve system activities in real-time applications. This work was taken from a public iris dataset. It has to be tested in non-cooperative datasets to see how it performs. Changing iris and distant iris are two further issues. These databases only have photos of the eye that are stationary and less than 50 meters from the sensor to the iris.

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