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Retina image assessment for microstructural difference detection

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Abstract

The dissimilarities in appearance of the iris texture patters can improve the individual's recognition and can strength the capabilities of multibiometrics systems. There is an important within-person variation or intraclass variation that produces different patters such as the geometry or iris pigmentation details that change over time or could be different when the right iris and left iris are analyzed. Moreover, the sensing environment such as ambient lighting variations, eye rotation due to the head tilt or inconsistent iris size due to the distance from the camera can also introduce within-person variation. In this paper, we apply the fuzzy edges detection, in a comparative fashion between right iris and left iris, to find the interoperability capability of a particular biometric trait determined primarily by genotype. In other words, we investigated the degree of variation of the irises of the same person. The structural similarity index measure (SSIM) is implemented to investigate the structural similarity between two iris codes. Prior to the similarity analysis, the segmented iris (i.e., annular area between pupil and sclera) is the edges detection based on the fuzzy edge is performed. This operation allows comparisons between the right iris and left iris without any influence of the stretch or dilation of the pupil induced by different illumination conditions. Also, we can estimate if the left and right irises belong to the same or to different individuals. The proposed approach is tested on the MMU1 Iris Database (with 225 images of the left eye and 225 images of the right eye). An average SSIM value of 0.9216, indicates that proposed iris biometrics model effectively differentiates between left and right eyes of the same person. Also, this result indicates that there is recognizable similarity between left and right irises. These results could be useful for certain applications devoted to detect anomalies in the human irises that could be associated to various diseases.

Keywords: iris; biometric recognition systems; fuzzy edge detection; iris segmentation

1. INTRODUCTION

A biometric system provides automatic identification of a person based on a unique trait or characteristic that the person possesses. Iris recognition is considered an accurate identification technology because it offers stability. Each individual has a unique iris that does not change over time, but it does vary either between the irises of identical twins or between the left and right eyes of the same person. The textural characteristics of the iris provide unique high-dimensional information that explains why iris recognition is considered the most reliable and accurate biometric identification system available [1].

Hanaa and Taha [2] showed that feature extraction influences the accuracy and reliability of the biometric system. Based on the analyzed strategies, they reported that statistical methods such as GLCM (Gray Level Co-occurrence Matrix) and LBP (Local Binary Patterns) provided low computational cost and high recognition rate (99.5% and 99.87%, respectively), which leads to an increase in the speed of the recognition system. Fang et al. [3] investigated the correlation between a person's left and right irises using a VGG16 convolutional neural network using the iris texture features. The experimental results of the two independent datasets revealed a high classification accuracy of 94.67%, respectively 94.83%, when the investigation was devoted to determine if both irises (left and right) belong to the same person or to different people. Tapia et al. [4] were concerned with predicting a person's gender based on analysis of iris texture features. They studied the application of the uniform LBP algorithm based on the histogram fusion for iris image in the polar representation to predict the person’s gender. The method gave an accuracy of 91.33%. Sindu et al. [5] proposed an algorithm to extract individual iris features using the combined biological features. They analyzed a pool of separate biological features and then selected one by one using suitable algorithms. The proposed method used crypt, pigment layer and Wölfflin nodule features of iris. The individual feature selection increases the reliability and accuracy of the recognition system compared to other systems. Zhao and Kumar [6] proposed a deep learning-based framework for accurate iris detection, segmentation and recognition. The proposed convolutional neural networks are able to perform a reliable primary segmentation by iris/non-iris pixels identification. An optimized network architecture generates spatially appropriate iris feature descriptors. The iris detection accuracy is in the range from 94.4% to 96.8%, for the three studied databases.

This study investigates the structural similarity between the right and left iris of the same person. The main contributions of this work are as follows:

- segmentation of left and right iris from MMU database images.
- improvement of the image quality (by sharpening the images using the Gaussian Low Pass filter or smoothing the image using a Laplacian filter).
- edge detection using the Fuzzy Edge Detection algorithm.
- the irises’ similarity comparison based on the average SSIM for both scenario: (i) the raw segmented images and (ii) segmentation results of the filtered images

The rest of the paper is organized as follows: Section 2 presents the mathematical approaches used in the processing algorithms; section 3 focuses on processing steps. Section 4 presents the results obtained from the three experiments and evaluates the SSIM values obtained. Finally, Section 5 provides a summary of our research and outlines our future intentions.

2. MATHEMATICAL APPROACHES

Many images contain a certain amount of noise, unexplained variations in data, disturbances in image intensity. Image analysis is often simplified if the noise is filtered out. In this study we exploit the filtering capability of sharpening image’s details by using the Gaussian low-pass filter or smoothing the image’s detail using a Laplacian filter.

To improve the quality of iris images, the first- and second-order derivative filters were used. An image A(x, y) provides the intensity of the gray levels at pixel position (x, y). The gradient vector of the image function [7] is:

$$\nabla A(\boldsymbol{x},\boldsymbol{y}) = \left[G_x G_y \right] = \left[\frac{\partial A(\boldsymbol{x},\boldsymbol{y})}{\partial x} \frac{\partial A(\boldsymbol{x},\boldsymbol{y})}{\partial y} \right] \tag{1}$$

- **The Laplacian operator**

The Laplace operator is computed using the second order derivative approximations of A(x, y). It searches the zero crossing points of the second order derivatives of the image function and establishes the rapid changes in adjacent pixel values that belong to an edge [7].

$$\nabla^2 A(x,y) = \frac{\partial^2 A(x,y)}{\partial x^2} + \frac{\partial^2 A(x,y)}{\partial y^2} \tag{2}$$

- **The Low Pass Gaussian operator** is used to improve the clarity of detail in human iris images. The 2D Gaussian discrete distribution G(x, y) is used to perform the convolution [8]

$$G(x,y)=\frac{1}{2\pi\sigma^2}e^{-\frac{x^2+y^2}{2\sigma^2}} \qquad (3)$$

where σ is the standard deviation of the distribution and drive the kernel size and the degree of smoothness.

- **The Laplacian of Gaussian (LoG) operator**

A combination of the Laplacian and Gaussian functions generates a new operator, LoG, centered on zero and with a Gaussian standard deviation σ:

$$LoG(x,y)=-\frac{1}{\pi\sigma^4}\left[1-\frac{x^2+y^2}{2\sigma^2}\right]e^{-\frac{x^2+y^2}{2\sigma^2}} \qquad (4)$$

The Gaussian operator suppresses the noise before using the Laplace operator for edge detection. LoG detects areas where the intensity changes rapidly, namely the function's values are positive on the darker side (pixel values around zero) and negative on the brighter side (pixel values around 255) [9].

- **Metric definition**

The Structural Similarity Index Measure (SSIM) investigates the structural information similarity of a person's left and right irises. For two given images A and B, the SSIM [10] is given by

$$SSIM(x,y)=\frac{(2\mu_A\mu_B+C_1)(2\sigma_{AB}+C_2)}{(\mu_A^2+\mu_B^2+C_1)(\sigma_A^2+\sigma_B^2+C_2)} \qquad (5)$$

where μ_A, μ_B are the mean pixels values for the two images σ^2_A, σ^2_B are the variances and σ_{AB} is the covariance. Constants C_1 and C_2 have been introduced to avoid division by zero. $C_1=(K_1\cdot L)^2, C_2=(K_2\cdot L)^2$, where $K_1 = 0.01$, $K_2 = 0.03$ and L= 255 for 8-bit component images.

3. METHOD

The hardware and software platform is a computer with the following configuration: Processor: Intel (R) Core (TM) i7-10870H, CPU 2.20 GHz, installed memory (RAM): 16GB, system type: 64bit operating system-based processor and application software: MATLAB R2018a.

The dataset contains 450 digital images (225 ocular images of the left eye and 225 ocular images of the right eye, respectively) belong to the Multimedia University Database (MMU1)[1] which is a public database consisting of eye images for IRIS-based biometry training models.

The first step of our method is devoted to the iris cropping. From an eyeball original iris image, a region around the annular area is cropped. This segmented image are the raw data for the further processing steps.

Proposed algorithm: The images

Input: gray images

Output: The Structural Similarity Index Measure (SSIM)

1. Import images;
2. Cropping images
3. Sharpening images with Low Pass Gaussian filter; smoothing edge with Fast Local Laplace filter
4. Edge Detection with Fuzzy Inference System (FIS)

[1] https://www.kaggle.com/datasets/naureenmohammad/mmu-iris-dataset

5. Compute SSIM for initially cropped images and for those enhanced using both filtering methods
6. Plot the Box and Whiskers graph to identify the differences between the SSIM coefficients.

Figure 1 shows the flowchart of the proposed method.

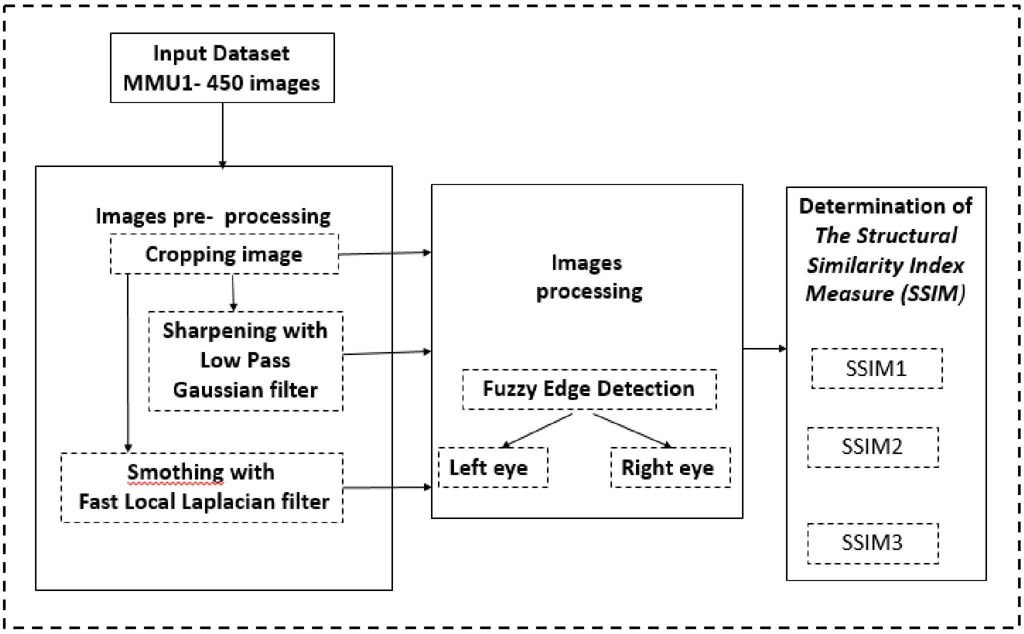

Fig. 1. Flowchart of the proposed method showing the steps involved in the processing of iris images

Low Pass Gaussian filter

The clarity of detail in images asked for a good contrast between different tons but without affecting the overall tone. A rapid transition from white to black results in a clear image with sharp details. Improving the clarity of details increases the contrast along the contours. The low-pass filter is used to remove the random noises and to reveal a background pattern. In the case of the uneven noise in retinal images, a noise always changes rapidly from pixel to pixel, as each pixel generates its own independent noise. Usually, a low-pass filter attenuates high frequencies and keeps low frequencies unchanged. The proposed method is based on the overlap between the low-pass filter and the Gaussian filter and has as results a better segmentation of the iris annular area [8]. Figure 2 displays an example of iris segmentation.

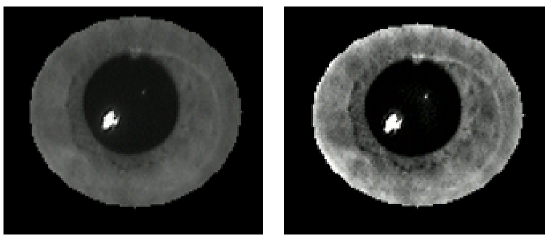

Fig. 2. a) Iris image; b) Image processed with Low Pass Gaussian filter

Fast Local Laplacian filter

The Fast Local Laplacian filter returns improved results for fine detail enhancement. It is well known that edges can be differentiated from fine-scale details [11]. Figure 3 highlights the difference between the original image and the one processed with the Laplace pyramid.

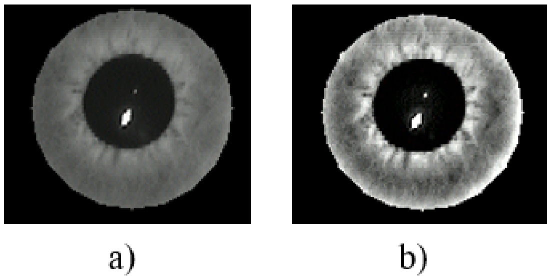

Fig. 3. a) Iris image; b) Image processed with Fast Local Laplacian filter

Fuzzy Edge Detection

Edge detection algorithms have the role of identifying and locating the discontinuities and significant transitions in the grey level values associated with pixels in the image [12, 14]. Edge detection is performed by analyzing the distribution of pixels and by evaluating their intensities around a given, fixed pixel. Strong variations between two neighborhood regions indicate that pixel as belonging to an edge [12, 15]. Each filter for edge detection is characterized by its own mask or window (i.e., a specific matrix of kernel coefficients (weights) or specific operations). This mask could have different size according to the expected result. It convolves the image and produces various discrete approximations with the final goal of highlighting edges.

In the recent years, fuzzy techniques have often been used for edge detection. Preprocessing is a necessary stage to correctly detect the edges and, usually, has three basic operations: image resizing, greyscale conversion and noise removal. In blurred images, the edge identification is a difficult task and it requires edges sharpening. Therefore, the fuzzy logic algorithm has been used to effectively deal with all these uncertainties. Fuzzy rule-based logic has three main parts: fuzzification of the image, modification of the membership value by fuzzy rules and image defuzzification. Fuzzification and defuzzification are the encoding and decoding of image data, which makes the image processing possible. The main unit of this system is the fuzzy inference system, which processes the image according to the changing membership values. The Mamdani Fuzzy Inference method has been used to obtain fuzzy sets by applying each inference rule to the input data. The output fuzzy set is obtained using an addition function. The output membership function value is decided according to the values of black, edge and white sets of the images [16].

In order to calculate the similarity index between the left and right irises of the same person, the edge detection via Fuzzy logic was applied on the three image categories: (a) segmented raw images; (b) image filtered using the Low Pass Gaussian filter and then segmented; and (c) image filtered using the Fast Local Laplace filter and then segmented. Figure 4 exemplifies the Fuzzy technique results.

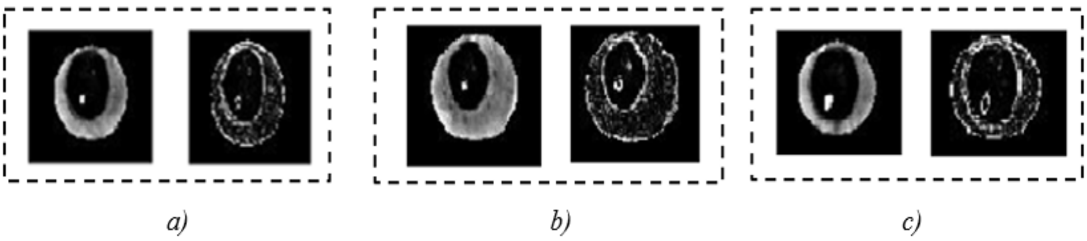

Fig. 4. a) Iris image / Edge detection with fuzzy technique; b) Low Pass Gaussian filter image/ Edge detection with fuzzy technique; c) Fast Local Laplacian filter image/Edge detection with fuzzy technique

4. RESULTS AND DISCUSSIONS

In order to demonstrate the applicability of the image processing for image quality enhancement, a dataset containing 450 images (225 left eye images and 225 right eye images) is investigated. SSIM is applied to iris enhanced images to confirm the efficacy of the proposed approaches. The performance of the proposed quality SSIM metric returned from the experimental approaches, is shown in the Box and Whiskers graph in Fig. 5.

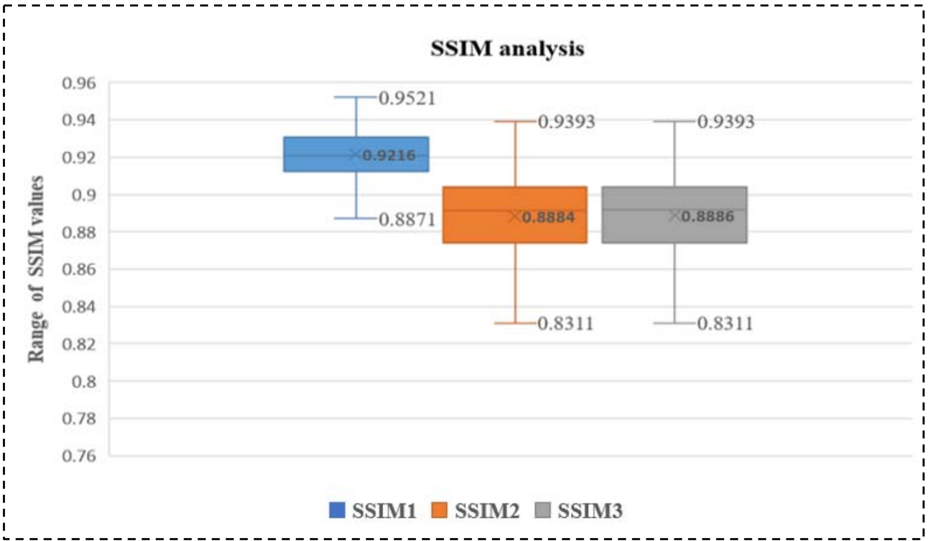

Fig. 5. The box-and-whisker plot for SSIM performance when the edges of left-right irises are evaluated via Fuzzy technique. SSIM 1 means segmented iris images; SSIM 2 for filtered image via the Low Pass Gaussian filter; SSIM 3 for filtered image via the Fast Local Laplacian filter. The horizontal line represents the median of the data. SSIM2 and SSIM3 have slightly negatively skewed distribution.

The results show a high-performance rate of similarity determined when the segmentation algorithm works on the raw irises images.

5. CONCLUSIONS

To conclude, in this paper, the ability of SSIM to investigate the structural similarity between left and right iris codes belonging to the same person has been analyzed. The experimental results showed the excellent performance of the segmentation method and Fuzzy Edge Detection algorithm on the raw data. Despite the fact that the images were processed to obtain sharpened details, the similarity index values were lower. This indicates that the original images were acquired under very good lighting conditions and the distance from the camera was correctly chosen in terms of texture highlighting.

An average SSIM value of 0.9216 indicates that the proposed iris biometry model effectively differentiates between the left and right eyes of the same person, and additional image quality enhancement methods are unnecessary.

In terms of further research, we intend to investigate other methods of improving the iris images quality on human iris images for the purpose of identifying a person or possible diseases related to iris features.

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