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A Robust Segmentation Method for Iris Recognition

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Abstract: In this paper, a new iris Segmentation method is presented. An iris recognition system acquires a human eye image, segments the iris region from the rest of the image, normalizes this segmented image and encodes features to get a compact iris template. Performance of all subsequent stages in an iris recognition system is highly dependent on correct detection of pupil-iris and iris-sclera boundaries in the eye images. In this paper, we present one such system which finds pupil boundary using image gray levels but uses Canny edge detection and Hough transform to locate iris boundary. Experiments are done on CASIA database of 756 iris images of 108 different persons with both left and right eyes images available per person. Experimental evaluation shows that the proposed system is accurate and efficient enough for real life applications. We are able to detect iris boundary almost 99.20% accurately with the proposed approach.

Keywords: Iris, Segmentation, Hough Transform, Canny, Hamming distance.

I. INTRODUCTION

Traditional methods of human identity verification such as using keys, certificates, passwords, etc., can hardly meet the requirements of identity verification and recognition in the modern society. These methods are either based on what a person possesses (a physical key, ID card, etc.) or what a person knows (a secret password, etc.), and have certain weaknesses. Keys may be lost, ID cards may be forged, and passwords may be stolen. In recent years, biometric identification is receiving growing attention from both academia and industry to overcome the aforementioned weaknesses. Biometrics can be defined as features used for recognizing and identifying a person based on his physiological or behavioral characteristics; and today, it is a common and reliable way to authenticate the identity of a living person. The process matches the individual's pattern or template against the records known by the system. As in all pattern recognition problems, the key issue is the relation between interclass and intra-class variability: objects can be reliably classified only if the variability among different instances of a given class is less than the variability between different classes.

Various biometric methods have been marshaled in support of this challenge. The resulting systems are based on automated recognition of retinal vasculature, fingerprints, hand shape, handwritten signature, face, gait and voice. Universality, uniqueness, permanence, measurability, noninvasiveness and user friendliness are the most important factors for evaluating different biometric methods. In addition, for identification applications requiring a large database of people's records, simplicity and efficient comparison of biometric IDs are necessary. Considering the above requirements, iris patterns appear as an interesting alternative for reliable visual recognition of persons when imaging can be done at distances of less than 1 meter (without contact) and when there is a need to search very large databases without incurring any false matches despite a huge number of possibilities. The pattern of human iris differs from person to person, even between twins. Since irises react with high sensitivity to light, causing the iris size and shape change continuously, counterfeiting based on iris patterns is extremely difficult. However, the pattern is rich detailed that it is also difficult to recognize it. The iris pattern can contain many distinguishing features such as arching ligaments, furrows, ridges, crypts, rings, corona, freckles, and a zigzag collarette. Thus, the iris is gifted with the great advantage that its pattern variability among different persons is huge. Iris begins to form in the third month of gestation and the structures creating its pattern are complete by the eighth month. Features of the iris remain stable and fixed throughout one's life. In addition, iris is protected from the external environment behind the cornea and the eyelid. These characteristics make iris a unique alternative for human recognition. Fig. 1 shows the sample iris image.

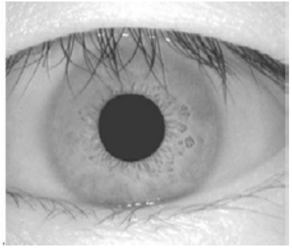

Figure. 1 Sample Iris Image

A general iris recognition system is composed of four steps. First, an image containing the user's eye is captured by the system. Then, the image is pre-processed to normalize for the scale and illumination effects of the iris and localize the iris in the image. Third, features representing the iris patterns are extracted. Finally, the recognition decision is made by means of matching. In contrast to current feature extraction approaches which are based on complex mathematical description of the iris texture, a very simple and novel approach is presented in this paper to extract features from the highly random iris. The method is based on the fact that any relation between subparts of a random texture is a random variable. The presented method is tested with 756 images of CASIA [9] image database and results of the method shows the proposed system is accurate and efficient enough for real life applications.

The paper is organized as follows. Section 2 describes pervious work on iris recognition methods. Section 3 presents details of the proposed approach. Section 4 gives experimental results obtained for the CASIA database version 1.

II. RELATED WORK

The French ophthalmologist Alphonse Bertillon seems to be the first to propose the use of iris pattern (color) as a basis for personal identification. In 1981, after considerable studies on the great variations of human eye iris, Flom and Safir [7] also suggested the use of iris as the basis for biometric recognition. In 1987, they approached to computer scientist J. Daugman of Cambridge University, England to develop iris identification software and published the first promising results in 1992 [15]. Later, similar efforts were reported by Wildes, Boles and Li Ma, whose methods differed both in the iris feature representation (iris signature) and pattern matching algorithms. The Wildes' solution [13] uses Hough transform for iris localization. He models eyelids with parabolic curves. A Laplacian pyramid (multi-scale decomposition) is applied to represent distinctive spatial characteristics of the human iris. Wildes applied a modified normalized correlation for the matching process.

The Boles' prototype [1] is based on a one dimensional representation of the grey level profiles of the iris followed by detecting the wavelet transform zero-crossings of the resulting representation. Li Ma [11] contributed Iris research progress by extracting Iris features by characterizing key local variations. The Daugman's system [3, 4] is implemented exploiting integro-differential operators to detect iris inner and outer boundaries. 2-D Gabor filters are applied to extract unique binary vectors constituting an iris code. Daugman uses a statistical matcher (logical exclusive OR operator) which computes the average Hamming distance between two codes (bit to bit test agreement). In terms of recognition rates (FAR, FRR), the commercial success of the patented Daugman's system speaks in his favour. Indeed, Daugman's mathematical algorithms have been contributing to a patented commercial solution. This biometric identification platform processes iris recognition through a specific optical unit that enables non-invasive acquisition of iris images, and a data processing unit.

III. PROPOSED APPROACH

Preprocessing is the initial stage in an iris recognition system. The histogram graph is obtained for the input eye image. Then Histogram Equalization is done to the input image to enhance the image for further process and it is also used for adjusting the contrast of the image using the image's histogram [10]. Once the preprocessing step is achieved, Segmentation is performed to separate the iris from the eye image. The iris inner and outer boundaries are located by finding the edge image using the canny edge detector. The advantage of canny edge detector over other edge detectors is that there is very less probability of not marking any real edges and marking unwanted edges. It uses a filter based on the first derivative of a Gaussian; hence the result is a slightly blurred version of the original image.

Canny edge detector mainly involves three steps such as, finding the gradient, adjust gamma correction, non-maximum suppression and the hysteresis thresholding. The threshold values that have been used are 0.19 and 0.2 (low and high threshold respectively). Adjust gamma correction controls the overall brightness of an image i.e. it adjusts the image gamma value. After the edge directions are known, non maximum suppression is applied to trace along the edge in the edge direction and suppress any pixel value that is not considered to be an edge. Hysteresis thresholding removes the weak edges below the low threshold. Fig. 2 shows the preprocessing steps which results in an edge detected image.

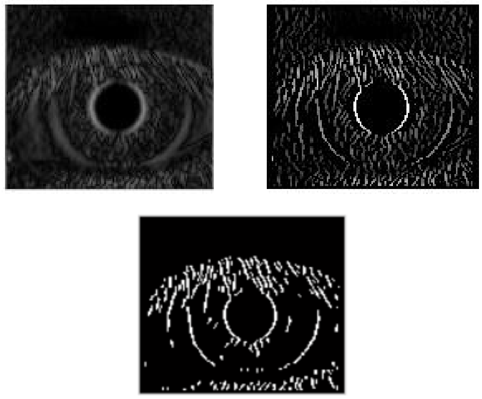

Figure. 2. (a) Adjust gamma correction, (b) Non-maximum suppression, (c) Canny edge image

Then Hough transform is employed to deduce the radius and centre coordinates of the pupil and iris regions [8]. Taking the edge pixels as the centre coordinates x_c and y_c, and with the desired radius r, circles are drawn according to the equation:

$$x_c^2 + y_c^2 = r^2 \qquad (1)$$

Iris localization is done by canny edge detector and curve fitting since iris is the annular part between pupil and sclera. The boundaries of the iris are modeled by two non-concentric circles and the eyelids are modeled by two parabolic curves. Daugman [5] used the following integro-differential operator to localize the iris:

$$max(r,\ x_0,\ y_0)\left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{r,x_0,y_0} \frac{I(x,y)}{2\pi r} ds \right| \qquad (2)$$

In this expression I(x, y) is an image containing eye. The integro differential operator searches over the image domain (x,y) for the maximum in the blurred partial derivative with respect to increasing radius r of the normalized contour integral of image along a circular arc ds of radius r and center coordinates (x0, y0). * denotes convolution and $G_\sigma(r)$ is a smoothing function subject to the value of convolution. By making use of the center and the radius of the iris and the pupil, we set the Cartesian coordinate system to dimensionless polar coordinate system. The proposed algorithm is based on the fact that there is some obvious difference in the intensity values of iris region and rest of the eye.

Iris normalization is done to improve the precision of matching. Thus the segmented iris region is converted to polar coordinate for further process through Daugman's rubber-sheet model. The rubber sheet model accounts for pupil dilation, imaging distance and non-concentric pupil displacement.

Figure. 3: Output of the Iris Normalization process.

Iris Feature Encoding is done using 2D Gabor Wavelets. Each isolated iris pattern is then demodulated to extract its phase information using quadrature 2D Gabor wavelets [2]. It amounts to a patch wise phase quantization of the iris pattern, by identifying in which quadrant of the complex plane each resultant phasor lies, when given area of the iris is projected onto complex-valued 2D Gabor wavelets:

$$h\{R_e, I_m\} = \mathrm{sgn}\{R_e, I_m\}\int_{\rho}\int_{\phi} I(\rho,\phi)e^{-i\omega(\theta_0-\phi)}.e^{-(r_0-\rho)^2/\alpha^2}e^{-(\theta_0-\phi)^2/\beta^2}\rho d\rho d\phi \tag{3}$$

where ***h{Re, Im}*** can be regarded as a complex-valued bit whose, real and imaginary parts are either 1 or 0 depending on the sign of the 2D integral; $I(\rho,\varphi)$ is the raw iris image in a dimensionless polar coordinate system that is size- and translation-invariant, and which also corrects for pupil dilation as explained in a later section; α and β are the multi-scale 2D wavelet size parameters, spanning an 8-fold range from 0.15 mm to 1.2 mm on the iris; ω is wavelet frequency, spanning three octaves in inverse proportion to β; and (r_0, θ_0) represent the polar coordinates of each region of iris for which the phasor coordinates *h{Re,Im}*are computed.

Feature matching is done using the effective method called hamming distance, which is used to match the two iris templates. The Hamming distance gives a measure of how many bits are the same between two bit patterns. Using the Hamming distance of two bit patterns, decision can be made as to whether the two patterns were generated from different irises or from the same one. In comparing the bit patterns *X* and *Y*, the Hamming distance, *HD*, is defined as the sum of disagreeing bits (sum of the exclusive-OR between *X* and *Y*) over *N*, the total number of bits in the bit pattern.

$$HD = \frac{1}{N}\sum_{j=1}^{N} X_j \oplus Y_j \tag{4}$$

If the hamming distance is 0, then the two templates are generated from the same iris or from different irises.

IV. EXPERIMENTS AND RESULTS

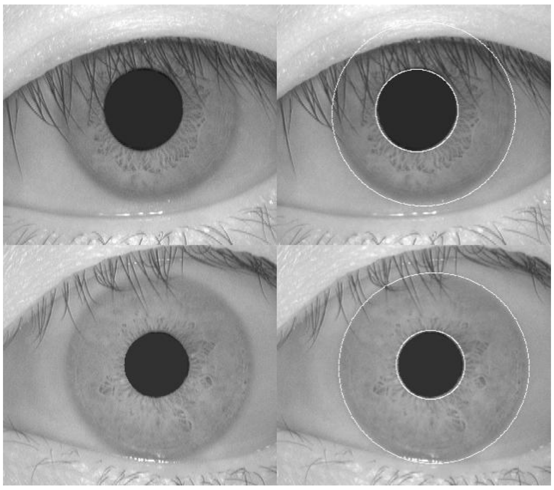

Figure 4: Original images and corresponding segmented images

We applied our algorithm to all dataset images and evaluated the accuracy for finding the pupil-iris and iris-sclera boundaries. The source code was written in MATLAB. The experiments were performed in MATLAB 7.8 running on 32 – bit Windows 7 Operating System. The PC was an Intel Core 2 Duo 2.00 GHZ processor with 2GB RAM. We verified the results manually. Table I summarizes our results. We compared the accuracy and speed of our system with the only (to the best of our knowledge) open source iris recognition implementation available, written by L. Masek and P. Kovesi [10]. The automatic segmentation model using Integro-differential equations and Hough transform proved to be successful.

The CASIA database provided good segmentation, since those eye images had been taken specifically for iris recognition research and boundaries of iris pupil and sclera were clearly distinguished. For the CASIA database, the Hough transform based segmentation technique managed to correctly segment the iris region from 658 out of 756 eye images, which corresponds to a success rate of around 87% as compared to the Hough transform based segmentation technique that managed to correctly segment the iris region from 624 out of 756 eye images, which corresponds to a success rate of around 83%.

Table 1: Comparison of Different Segmentation Techniques

Method	No. of eye images	Properly Segmented	Accuracy
Masek and Kovesi's method	756	646	85.5%
Daugman's Method	756	658	87%
Hough Transform	756	624	82.5%
Proposed Method	756	750	99.2%

V. CONCLUSION AND FUTURE SCOPE

This paper has presented an iris recognition system using an effective edge detection method. Automatic segmentation was achieved by canny edge detection through the use of the Hough transform for localizing the iris and pupil regions, occluding eyelids. Segmented Iris image is normalized using Rubber-sheet model proposed by J. Daugman and finally the two irises were matched using hamming distance. With the 756 eye images that are taken from the CASIA database, we got the success rate of 99.2% which is best as compared to other methods compared in the paper. Iris Segmentation and Normalization are significant parts of an efficient Iris Recognition system and there is always a scope of betterment so it is seen to assess the quality of input iris image before segmentation, to consider the noise factors like eyelashes, eyelids, specular reflections, spectacles, lenses etc. in more details so that preventive measures for removal of their effect on the overall accuracy of the system can be minimized as a future scope of the current work.

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