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Iris Segmentation and Normalization using Daugman's Rubber Sheet Model

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Abstract**—** A biometric system provides automatic identification of a human being based on some unique physical or behavioral feature of the individual. The world today is making rapid progress in its quest to realize the dream of a creating a user friendly, customer caring ambience. With every new dream comes the nightmare of a security of the system lapse which may allow the misuse of the system. A major success in trying to bridge the advent of a security lapse is the use of biometrics. Biometric technologies such as fingerprint, facial recognition, and iris recognition are deployed for verification and/or identification in applications such as access control, border management, and Identification systems. Iris is regarded as the most reliable and accurate biometric identification system being used in modern era. Most commercial iris recognition systems use patented algorithms developed by Daugman and these algorithms are able to produce perfect recognition rates. However, published results have usually been produced under favorable conditions, and there have been no independent trials of the technology. The work presented in this paper developing an open-source" for segmentation and normalization of human iris image for iris recognition system using Hough Transforms for iris image segmentation and Daugman's Rubber Sheet Model for image normalization in MATLAB.

Keywords**—** Biometrics, Iris, Segmentation, Iris Normalization, Hough Transforms, Rubber Sheet Model, MATLAB.

I. Introduction

THE Biometric technology deals with recognizing the identity of individuals based on their unique physical or behavioral characteristics. Physical characteristics such as fingerprint, palm print, hand geometry and iris patterns or behavioral characteristics such as typing pattern and hand-written signature present unique information about a person and can be used in authentication applications. The developments in science and technology have made it possible to use biometrics in applications where it is required to establish or confirm the identity of individuals.

Iris patterns are formed by combined layers of pigmented epithelial cells, muscles for con-trolling the pupil, stomal layer consisting of connective tissue, blood vessels and an anterior border layer [1] [8]. The physiological complexity of the organ results in the random patterns in iris, which are statistically unique and suitable for the biometric measurements [7]. In addition, iris patterns are stable over time and only minor changes happen to them throughout an individual's life [3]. It is also an internal organ, located behind the cornea and aqueous humor, and well protected from the external environment. The characteristics such as being protected from the environment and having more reliable stability overtime, compared to other popular biometrics, have well justified the ongoing research and investments on iris recognition by various researchers and industries around the world. For instance, the developed algorithm by Daugman [7], which is known as the state-of-the-art in the field of iris recognition, has initiated huge investments on the technology for more than a decade. The history of iris recognition goes back to mid 19th-century when the French physician, Alphonse Bertillon, studied the use of eye color as an identifier [2]. However, it is believed that the main idea of using iris patterns for identification, the way we know it today, was first introduced by an eye surgeon, Frank Burch, in 1936 [6]. In 1987, two ophthalmologists, Flom and Safir, patented this idea [3] and proposed it to Daugman, a professor at Harvard University, to study the possibility of developing an iris recognition algorithm. After a few years of scientific experiments, Daugman proposed and developed a high confidence iris recognition system and published the results in 1993 [7]. The proposed system then evolved and achieved better performance in time.

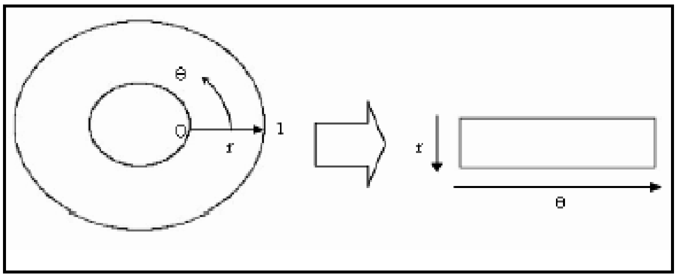

Fig.1 Daugman's rubber sheet model shows how a circular shape (iris) can be normalized into definite (rectangular) template of iris patterns.

The overall performance of an iris recognition system relies on the performance of its subsystems. The qualities of the image acquisition, segmentation, normalization and feature encoding, altogether, define the performance of the system. The main objective of the study is to provide an automated segmentation and normalization system based on Daugman's rubber-sheet model using Hough Circles and Canny edge detection techniques on iris images to create a highly accurate pre -requisite for matching algorithms in order to build an efficient and reliable iris recognition system and to test it on CASIA database [9].

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II. METHODOLOGY

The automated segmentation and normalization of iris images is done using Hough transforms and image registration based on Cartesian coordinates as discussed below.

A. Segmentation

Properly detecting the inner and outer boundaries of iris texture is significantly important in all iris recognition systems. The segmentation techniques model iris boundaries and the two eyelids with simple geometric models. Pupil and limbus are often modelled as circles and the two eyelids are modelled as parabolic arcs. In segmentation, it is desired to distinguish the iris texture from the rest of the image. An iris is normally segmented by detecting its inner (pupil) and outer (limbus) boundaries [4]. Well-known methods such as the Integro-differential, Hough transform and active contour models have been successful techniques in detecting the boundaries.

Hough transforms are employed here, as segmentation technique. Hough transform is a standard image analysis tool for finding curves that can be defined in a parametrical form such as lines, polynomials and circles. The recognition of a global pattern is achieved using the local patterns. For instance, recognition of a circle can be achieved by considering the strong edges in an image as the local patterns and searching for the maximum value of a circular Hough transform.

The MATLAB functions designed for iris image segmentation are discussed as under.

createiristemplate: generates a biometric template from an iris eye image.

segmentiris: performs automatic segmentation of the iris region from an eye image. also isolates noise areas such as occluding eyelids and eyelashes.

addcircle: circle generator for adding weights into a hough accumulator array.

adjgamma: for adjusting image gamma

circlecoords: returns the pixel coordinates of a circle defined by the radius and x, y coordinates of its centre .

canny: canny edge detection - function to perform canny edge detection.

findcircle: returns the coordinates of a circle in an image using the hough transform and canny edge detection to create the edge map.

findline: returns the coordinates of a line in an image using the hough transform and canny edge detection to create the edge map.

houghcircle: takes an edge map image, and performs the hough transform for finding circles in the image.

hysthresh: hysteresis thresholding: function performs hysteresis thresholding of an image.

linecoords: returns the x and y coordinates of positions along a line.

nonmaxsup: function for performing non-maxima suppression on an image using an orientation image. it is assumed that the orientation image gives feature normal orientation angles in degrees (0-180).

B. Normalization

Normalization refers to preparing a segmented iris image for the feature extraction process. In Cartesian coordinates, iris images are highly affected by their distance and angular position with respect to the camera. Moreover, illumination has a direct impact on pupil size and causes non-linear variations of the iris patterns. A proper normalization technique is expected to transform the iris image to compensate these variations. An image registration technique for normalizing iris textures is implemented in this study. In this method, a newly acquired image would be aligned with an image in the database, so that the comparison is performed easily. Normalization process is based on a different approach compared to Daugman's method.

In this method, normalization is performed in the matching time. Comparing to Daugman's approach, the normalization method would be time consuming in identification applications. However, for verification purposes the method is capable of compensating unwanted factors such as variations in rotation and scale. The MATLAB functions designed for iris image segmentation are discussed as under.

normaliseiris: normalization of the iris region by unwrapping the circular region into a rectangular block of constant dimensions.

encode: generates a biometric template from the normalized iris region, also generates corresponding noise mask

gaborconvolves: function for convolving each row of an image with 1d log-gabor filters.

III. RESULTS

The results obtained from segmentation and normalization process are discussed in this section along with the implementation of a new Graphical User Interface in MATLAB.

A. Output 1: the user-interface designed in MATLAB

The designed user interface for Iris Image Segmentation and Normalization in Matlab is shown in Fig.2.

B. Output 2: the original input image

The original input image is shown in Fig.3. The image is selected by clicking in the "**Select Image**" button on the GUI and the output is shown as under.

Output 3: the detection of pupil and iris boundary

The output image after detection of Pupil and Iris boundary of the selected original input image for Iris Image Segmentation and Normalization in Matlab. This is done by using hough circles. The detected boundaries are shown using circles of white borders in the Fig. 4.

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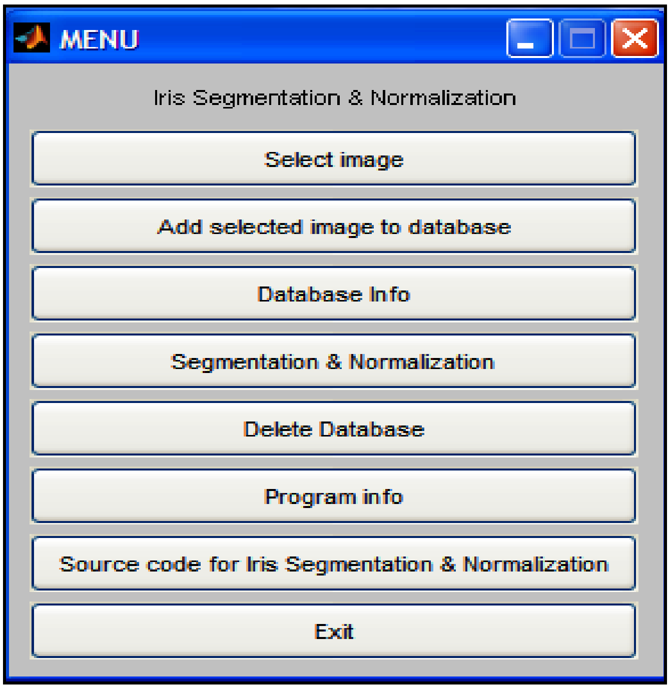

Fig. 2. MATLAB user-interface for iris segmentation and normalization.

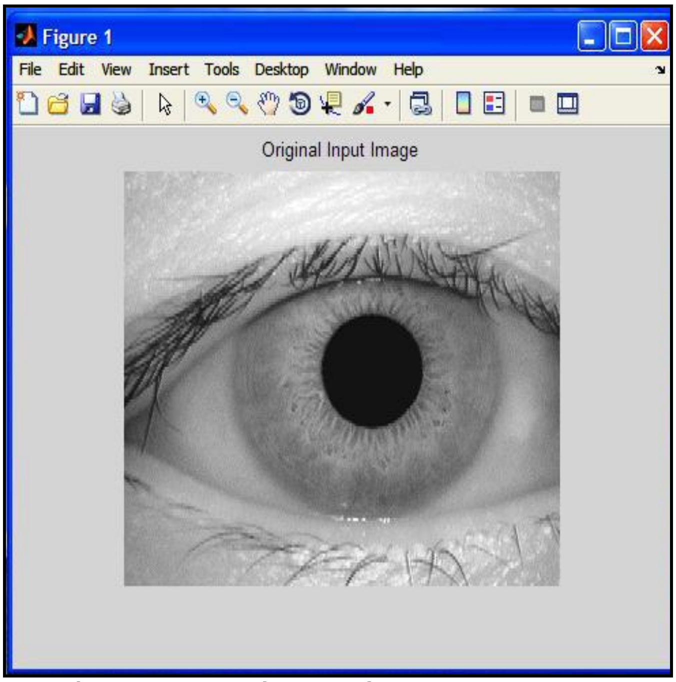

Fig. 3. The input iris image to be processed.

Output 4: the edge detection of eyelids and iris

The output image edge detection of the selected original input image for Iris Image Segmentation and Normalization in Matlab (Fig, 5). This is application of canny edge detection.

Output 5: top and bottom eyelid segmentation

The output segmented image after detection of Pupil and Iris boundary with top and bottom eyelid detection. This function is important as it removes the intruding eyelids over the detected iris region of interest and makes it possible to dissociate this unwanted artifacts from the effective area required for normalization and feature encoding, thus generating a good iris template pattern for matching. The eyelid detection is shown in the Fig. 6.

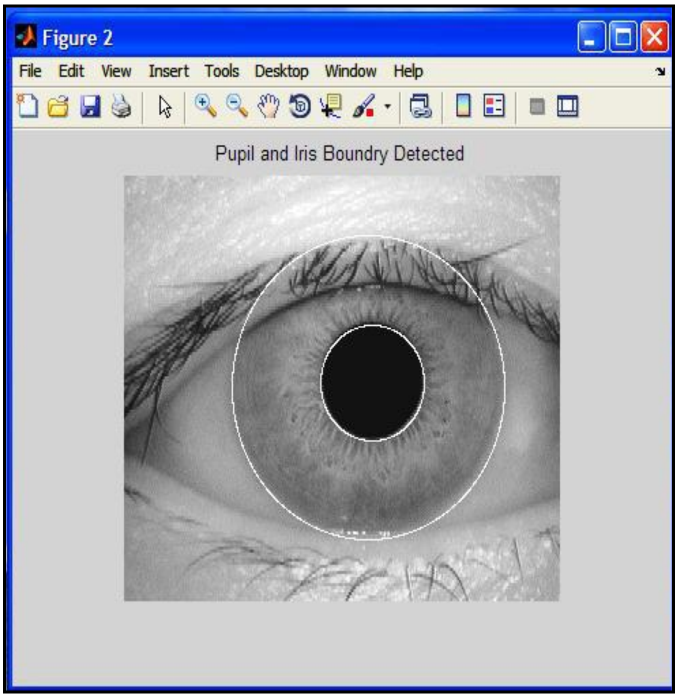

Fig. 4. Boundaries of iris and pupil of the eye detected.

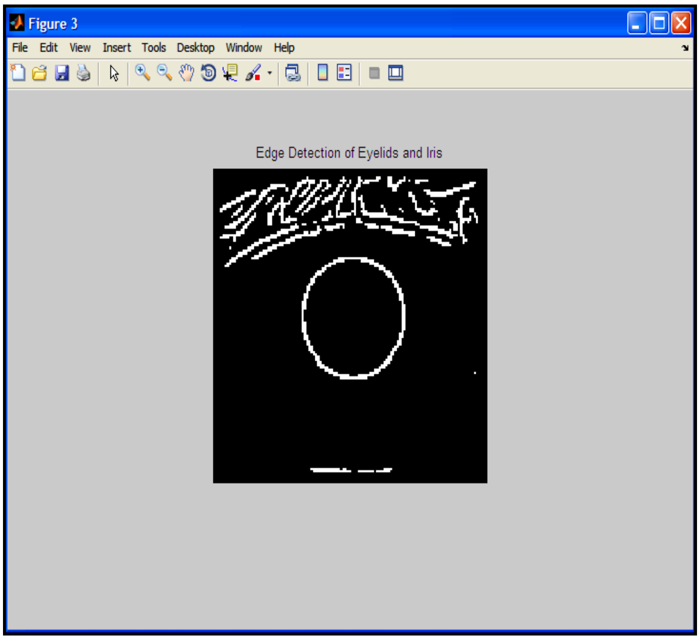

Fig. 5. Edge Detection.

Output 6: the normalized iris image

The output normalized image (Fig. 7) after detection of Pupil and Iris boundary along with top and bottom eyelid detection and elimination for Iris Image Segmentation and Normalization in Matlab. The function used here is normaliris.

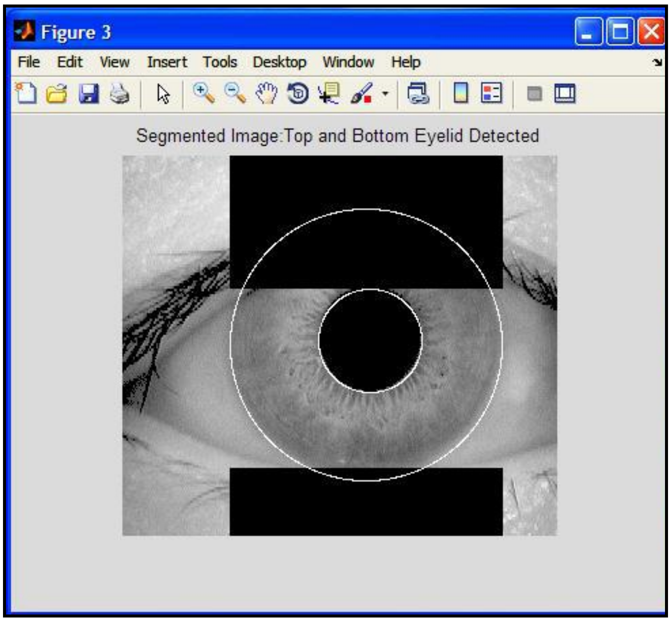

Fig. 6. Segmentation of top and bottom eyelid

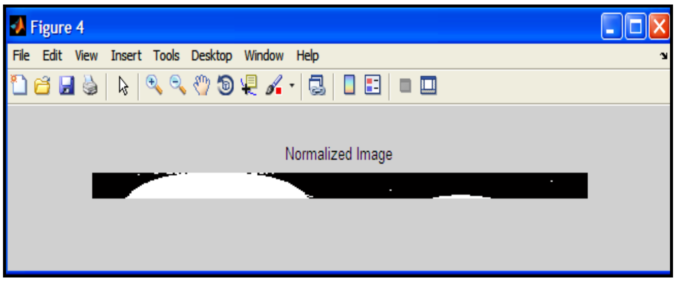

Fig. 7. Normalized Iris Patterns.

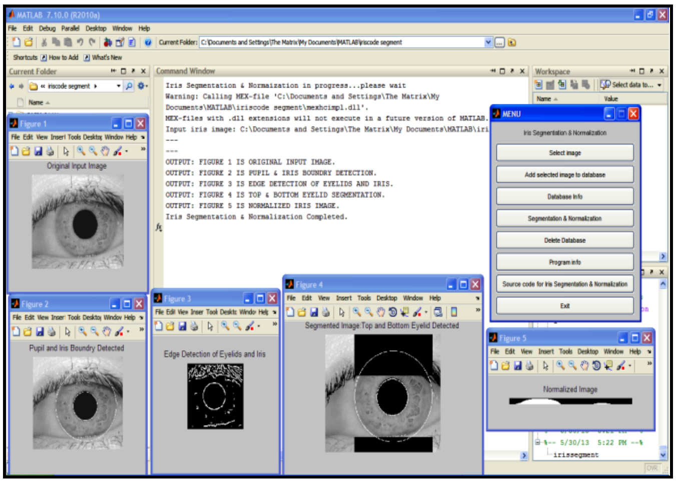

Fig. 8. Final MATLAB Output Window

Output 7: the final MATLAB output window

The final MATLAB output window with all the final iris image segmentation and normalization results is shown in Fig. 8.

IV. Conclusion

This study has presented Iris segmentation and normalization system, which was tested using CASIA database of gray scale eye images in order to verify the claimed performance of iris recognition technology and application of Matlab in Digital Image Processing. Firstly, an automatic segmentation algorithm was presented, which would localize the iris region from an eye image and isolate eyelid, eyelash and reflection areas. Automatic segmentation was achieved through the use of the circular Hough transform for localizing the iris and pupil regions, and the linear Hough transform for localizing occluding eyelids. Thresholding was also employed for isolating eyelashes and reflections. Next, the segmented iris region was normalized to eliminate dimensional inconsistencies between iris regions. This was achieved by implementing a version of Daugman's rubber sheet model, where the iris is modeled as a flexible rubber sheet, which is unwrapped into a rectangular block with constant polar dimensions.

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