Efficient Iris Segmentation Based on Converting Iris Images to High Dynamic Range Images

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Abstract—Iris segmentation plays a very vital role for iris recognition. In the meantime, high quality image with many details has important role in segmentation. Using High Dynamic Range technique, image details can be increased. In this paper, using converting iris images into HDR iris images, segmentation operation is performed. Images are changed to different exposure manually, then are combined and produced HDR image. HDR images and normal images are tested and compared separately with available segmentation methods. Experiment results show that, the proposed method can segment iris images accurately and can be used for different types of iris images.

Keywords—Iris, High Dynamic Range, HDR images, Segmentation, Identification, Iris Recognition.

I. INTRODUCTION

Iris segmentation is to locate the valid part of the iris for iris biometrics, including finding the pupillary and limbic boundaries of the iris, localizing its upper and lower eyelids if they occlude and detecting and excluding any superimposed occlusions of eyelashes, shadows or reflections [1]. The centrality of segmentation to effectiveness of any iris recognition system cannot be overemphasized [2].

The performance of an iris segmentation algorithm is affected by the image acquisition process. A majority of iris recognition systems require a significant amount of user cooperation during image acquisition to provide good recognition performance. For an iris image acquired under near-ideal conditions, iris segmentation can be accomplished using simple image-processing techniques. This is based on the observation that both the iris boundaries show significant variation in pixel intensities across their contours. However, when an iris image is acquired under non-ideal conditions, segmentation becomes a challenging task [3].

Researchers are constantly researching the iris segmentation, to further improve the success rate of identification. Vast progress has been made in this case, and many methods have been proposed. Improving the quality of images is the interested way of researchers. Image processing techniques can improve the quality and increase the success rate of identification. In this paper, High Dynamic Range (HDR) technique has been used to increase details of iris images. By applying this technique, the conventional image converts to HDR image with very high details. In this mode the machine can operate better segmentation, boundaries are well represented, so the success rate of identification is increased. This technique can be applied on the color images and infrared images. The noisy or low quality images can be segmented by these technique. The obtained results of the proposed method indicate the success of this method on iris segmentation.

Rest of the paper is structured as follows: section II consists of related works, section III describes proposed method. Section IV include experiments and results. Section V represents conclusions.

II. RELATED WORKS

Iris segmentation is performed by different methods. Different algorithms and techniques play an important role in segmentation. As mentioned earlier, segmentation is an important step in iris biometrics and the low accuracy may lead to failure of identification. As stated, the aim of this step is finding of the iris boundary and other parts of the eye and also reducing of noise and increasing image quality. This step, depending of the type of the image, can be included preprocessing and main processing stages. Preprocessing is the stage in which the image can be improved for the main processing stage. The related works in preprocessing step is described at the following.

Zheng et al. [4] used the conversion into HSV color space method. Pupil center detection and radius estimation, they mainly deal with detecting the pupil center and estimating its radius. Pupil center is located in H channel of HSV color space. After that the radius of the pupil is estimated and then refined by a simple search algorithm. The HSV color space (Hue, Saturation, Value) is often used by people because it is more consistent with how people experience color better than the RGB color space is. Zuo et al. [5] and Shuckers et al. [6] exploited the specular reflections detected by PDE based inpainting technique. To reduce or even remove specular reflections they employ a Partial Differential Equation (PDE) based inpainting technique. First, specular reflections are localized through hard thresholding. Then, these localized regions are refined based on the shapes and connectivity properties of the masked areas. To compensate for the missing data, a sparse linear algebra and PDE discretization based inpainting procedure is carried out on the refined localized...
The iris is then binarized using a threshold value. As expected, the preprocessing stage. The iris image is first smoothed using a 2-2-D Median filter to detect the pupillary boundary in the relatively smaller regions associated with the eyelashes. eyelashes) are expected to fall below this intensity value. A 2-apart from the pupil, other dark regions of the eye (e.g., specular reflection regions. Dobes et al. [7] adopted histogram equalization and Gaussian blur for preprocessing stage. The image histogram equalization was performed in dependence of the image quality. The Gaussian filtration was utilized in order to minimize a detection of false edges, noise and inappropriate details. The preprocessing adaptive histogram equalization was performed on the dark face images where the necessary details were hidden in dark areas and the intensity levels were within a small range. Their dynamic ranges should be large enough for the further correct image processing, especially for the edge detection. Then a suitable image filtration must be done by convolving the image with a Gaussian mask. The optimum value of variance of the Gaussian mask, which was set experimentally, depends on the level of detail and noise in the image. Such value is to preserve only the significant edges after the edge detection which was applied in the next step. Proença and Alexandre [8] and Kennell et al. [9] represented histogram equalization and binarization for improves the contrast between each eye’s region, thus contributing to the correct algorithm segmentation. Binarization is Applying a threshold on an image before the operator’s execution enables the maximization of the contrast between the regions belonging to the iris and the remaining ones. Ross and Shah [10, 11] used 2-D Median filter to detect the pupillary boundary in preprocessing stage. The iris image is first smoothed using a 2-D Median filter and the minimum pixel value, is determined. The iris is then binarized using a threshold value. As expected, apart from the pupil, other dark regions of the eye (e.g., eyelashes) are expected to fall below this intensity value. A 2-D Median filter is then applied on the binary image to discard the relatively smaller regions associated with the eyelashes. This reduces the number of candidate regions detected as a consequence of thresholding based on the median-filtered binary image. Poursaberi and Araabi [12] provided image morphological operators and suitable threshold for preprocessing stage. They used 320 × 280 grayscale images. Puhani et al. [13] utilized image binarization and threshold of the local Fourier spectral density. The method computes the Fourier spectral density for each pixel using its neighborhood and then performs a thresholding that results in a binary image giving the iris region approximately. Further image processing operations on the binary image could segment the eyeball region correctly. Further image processing operations on the binary image could segment the eyeball region correctly. Sahmoud and Abuhaiba [14] and Peihua Li et al. [15] constructed K-Means clustering based on the gray-level co-occurrence histogram and an improved Hough transform to localize the limbic boundary. Shashidhara and Aswath [16] provided the Gaussian filter and smoothen the image for reduce the noise. For applying the filter they convert the RGB image into grayscale level and then convert the image into black & white required threshold level. Fei Yan et al. [17] used Total Variational method. The Total Variational (TV) is an image processing method based on variational method and PDE. TV-L2 is a model using total variation as the regularization term to decompose image. Singh et al. [18] exploited thresholding and morphological operation. The opening and hole-filling by darkness operation is employed to remove the reflection.

In another studies, He and Shi in [19], Basit and Javed in [20] also used image binarization and morphologic operations for preprocessing stage. Morphologic operators to eliminate eyelashes used by Zaim in [21]. Tan et al. [22] utilized image clustering to perform rough eye localization. Rathgeb et al. [23] used reflection mask detection. Zhaofeng He et al. [24] represented a bi-linear interpolation method to fill the reflections. Benboudjema et al. [25] adopted Triplet Markov Field (TMF) to efficient iris segmentation. Abhyankar and Schuckers [26] exploited a Wavelet Based Quality Measure (WIMQ) to assess the quality of iris images.

III. PROPOSED METHOD

In this section, High Dynamic Range images are briefly talked, then converting iris image algorithm to HDR iris image are described.

A. About High Dynamic Range images

High Dynamic Range (HDR) images become more popular. This is because they can represent the acquired scenes using high dynamic ranges of luminance compared to conventional Low Dynamic Range (LDR) images [27]. Dynamic range in photography describes the ratio between the maximum and minimum measurable light intensities (white and black, respectively) [28]. In the real world, one never encounters true white or black, only varying degrees of light source intensity and subject reflectivity. Therefore the concept of dynamic range becomes more complicated, and depends on whether you are describing a capture device, a display device, or the subject itself. Just as with color management, each device within the above imaging chain has their own dynamic range. In prints and computer displays, nothing can become brighter than paper white or a maximum intensity pixel, respectively. In fact, another device not shown above is our eyes, which also have their own dynamic range. Translating image information between devices may therefore affect how that image is reproduced. The concept of dynamic range is therefore useful for relative comparisons between the actual scene, camera, and the image on your screen or in the final iris segmentation.

Light intensity can be described in terms of incident and reflected light; both contribute to the dynamic range of a scene. Scenes with high variation in reflectivity, such as those containing black objects in addition to strong reflections, may actually have a greater dynamic range than scenes with large incident light variation. Photography under either scenario can easily exceed the dynamic range of camera, particularly if the exposure is not spot on. Accurate measurement of light intensity, or luminance, is therefore critical when assessing dynamic range. Here the term illuminance to specify only incident light is used. Both illuminance and luminance are typically measured in candelas per square meter (cd/m²). Approximate values for commonly encountered light sources are shown in Figure 1.
Here the vast variation possible for incident light are seen, since the above diagram is scaled to powers of ten. If a scene were unevenly illuminated by both direct and obstructed sunlight, this alone can greatly increase a scene's dynamic range.

B. HDR iris images algorithm

For most applications it is enough to use 3 input images with an exposure difference in 2EV to cover all the dynamic range [29]. In this paper, an iris image into 3 LDR images with different EV (Exposure Value) is converted, manually. Then LDR images are merged into a single HDR image. The algorithm scheme is shown in Figure 2.

Since the LDR iris image with different EV are prepared, the exposure blending is applied to produce an image with extended dynamic range properties. Normally exposed image is selected as a reference one. Overexposed pixels of this image are combined with same pixels in underexposed image. And underexposed pixels of normally exposed image are combined with an overexposed one. In other words, we combine dark pixels of normally exposed image with pixels in over exposed image which are brighter. Similar bright pixels in a reference image are combined with the darker image. Similar to [29], mathematically this could be formalized as (1).

\[
I^*_{i,j} = \begin{cases} 
    b(I^0_{i,j}).I^0_{i,j} + (1-b(I^0_{i,j})).I^{+2}_{i,j}, & \text{if } I^0_{i,j} < 127.5 \\
    b(I^0_{i,j}).I^0_{i,j} + (1-b(I^0_{i,j})).I^{-2}_{i,j}, & \text{if } I^0_{i,j} > 127.5
\end{cases}
\]  

(1)

where \(I^0\) is the combined image, \(I^{-2}\), \(I^{+2}\) and \(I^0\) are underexposed, overexposed and normally exposed iris images respectively and \(b\) is blending coefficient, computed by a Gaussian-like function (2) centered at 127.5 (255/2). The peak of the function is selected to be in the middle of feasible intensity range.

\[
b(x) = \exp\left(-4\frac{(x-127.5)^2}{127.5^2}\right)
\]  

(2)

To minimize computational cost, values of (2) were precalculated for all possible values of \(x\). HDR iris image generated from a LDR iris image is shown in Figure 3. As can be seen, right image has more clarity and details in comparison with the left image. Also, the boundaries are well separated.

IV. EXPERIMENTAL RESULTS

Near Infra-Red (NIR) images of natural scenes usually have better contrast and contain rich texture details that may not be perceived in visible light photographs [30]. This statement is also true for iris images. In Figure 3 dynamic range on the color (RGB) iris image is applied. But, in this paper we used CASIA iris database that is taken especially the NIR illumination scheme [31]. So, the proposed method on NIR images of CASIA iris database is applied and received interesting results. In Figure 4 HDR iris image generated from NIR CASIA iris image is shown.

To test the segmentation, Daugman’s Integro-Differential operator [32, 33, 34] and Wildes’s Edge detection and Hough transform method [35] are used. The test is in the way that, first the stated methods on normal images are applied and the results are recorded. Then the stated methods on HDR images are applied, and compared the results with previous results and obtained the rate of improvement segmentation.

In Figure 4, in the top row, the middle image is the normal image of CASIA database without changing the EV and
considered the basis of the EV Initialization. In the left image EV = -2 is intended. EV value for the right image +2 is intended, too. Eventually, the generated HDR image of the three images is shown in the bottom row.

We observed that the number of images in the database that were not segmented correctly, can be correctly segmented after converting to HDR image. The rest of database images that were correctly segmented, with the proposed method and after converting images to HDR images, has been improved in the segmentation and thus the accuracy of segmentation is increased.

In the Figure 5 the sample of image database which is correctly segmented after converting to HDR image is shown. In the Figure 6 and 7, samples of images that are improved in the segmentation after converting to HDR images, are shown. In the Table I, the complete results of the proposed method are completely described.

![Normal iris image segmentation](image1)
![Correctly segmented after converting to HDR](image2)

**Fig. 5.** Correctly segmentation after converting to HDR image

![Normal iris image segmentation](image3)
![HDR iris image segmentation](image4)

**Fig. 6.** Sample 1: improved segmentation after converting to HDR image

![Normal iris image segmentation](image5)
![HDR iris image segmentation](image6)

**Fig. 7.** Sample 2: improved segmentation after converting to HDR image

As can be seen in Table I, out of 756 normal images of CASIA iris database, by using Daugman method, accuracy rate of iris segmentation is 57.67%. But out of 756 HDR images, accuracy rate is 77.38%. The results of Daugman method are difficult for comparison. If we use the algorithm which is given in [32] then the segmentation represents 57.67% of precision. If we take into account the improvements that were done by other authors then Daugman method presents 100% of precision. Using Wildes method, out of 756 normal images of database, accuracy rate of iris segmentation is 86.50%. Out of 756 HDR images, accuracy rate is 99.47%. As can be seen accuracy rate is higher, by using proposed method.

<table>
<thead>
<tr>
<th>Methodology</th>
<th>Accuracy rate of normal iris images</th>
<th>Accuracy rate of HDR iris images (Proposed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daugman [32]</td>
<td>57.67 %</td>
<td>77.38 %</td>
</tr>
<tr>
<td>Daugman (Improved)</td>
<td>100 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Wildes [35]</td>
<td>86.50 %</td>
<td>99.47 %</td>
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</tbody>
</table>

### V. CONCLUSION

Today, the image processing is used extensively in many areas. Identification systems using image processing have been able to make much progress on security issues. Identification based on iris recognition is one of the remarkable biometric methods. One of the most important steps of identification based on iris recognition is iris segmentation step. Accuracy and effectiveness of this step, effects on the next steps of iris recognition. Many methods have been proposed to improve the segmentation. In this paper, by using of converting images to High Dynamic Range image, improvement on segmentation is made. HDR image is generated from input images using exposure blending technique. The proposed method requires no camera information or additional calibration process. Described technique could be used as a preprocessing step in color iris recognition, iris recognition at a distance or move, iris feature extraction, computer vision applications, robot localization and others.

### REFERENCES


