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BIRD: Watershed Based IRis Detection for mobile devices ☆

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ABSTRACT

Communications with a central iris database system using common wireless technologies, such as tablets and smartphones, and iris acquisition out of the field are important functionalities and capabilities of a mobile iris identification device. However, when images are acquired by means of mobile devices under uncontrolled acquisition conditions, noisy images are produced and the effectiveness of the iris recognition system is significantly conditioned. This paper proposes a technique based on watershed transform for iris detection in noisy images captured by mobile devices. The method exploits the information related to limbus to segment the periocular region and merges its score with the iris' one to achieve greater accuracy in the recognition phase.

1. Introduction

Iris detection is one of the most powerful biometrics for security applications, e.g., physical access control, as it is witnessed by the wide literature in the field [2–4]. In fact, iris acquisition devices, based on near infrared or visible light technology, are characterized by non-invasiveness. Moreover, the iris of any individual subject is characterized by uniqueness, external visibility and remains the same during the entire life of the subject. Consequently, iris recognition systems are generally preferable with respect to systems based on other biometrics.

It is possible to use simple image processing tools during acquisition if you are able to control the lighting conditions and the distance of the person whose iris must be recognized. Unfortunately, however, even in the case of a cooperative subject, the performance of an iris recognition system decays significantly, if the lighting conditions are irregular, the acquisition is accomplished on the move or mobile devices are used. Tan et al. [15] have shown that with regard to segmentation of iris and periocular area, the process of localization and transformation of objects of interest in images acquired with visible light in an uncontrolled environment presents many more pitfalls. This work, as well as [10], addresses the problem in the context of iris acquisition on the move, but differently from [10], this article is specifically oriented to the case of acquisition done by means of mobile devices.

Iris is delimited by sclera and pupil, which represent the lightest and the darkest parts of the eye, respectively. A number of tasks have to be accurately accomplished by an iris recognition system, such as acquisition of the eye image, iris segmentation, iris coding and recognition. In particular, accuracy is fundamental during iris segmentation, to generate an iris code able to improve the performance of the recognition system.

In this paper we introduce the watershed Based IRis Detection (BIRD) technique for smart mobile devices, which is the follow up of a technique we have recently suggested [7,8]. BIRD exploits the use of the watershed transform to identify more precisely the iris boundary and, hence, to obtain a more accurately computed code for iris recognition.

A positive feature of the watershed transform is that the contours delimiting the regions into which an image is divided are mostly placed where human observers perceive them. In fact, the watershed transformation is a growing process performed generally on the gradient image, where the edges are enhanced. This feature should allow to correctly detect the limbus boundary. In turn, a negative feature is over-segmentation, i.e., the image may be partitioned into a number of parts that is remarkably larger than expected. Over-segmentation is particularly evident when all the regional minima in the gradient image are considered as seeds for the growing process. A common strategy to overcome this drawback is to adopt region merging and/or seed selection to reduce the number of watershed regions. However, in the case of eye images, processes for over-segmentation reduction cannot be stressed. Otherwise, some weak boundaries between sclera and limbus (light eye case) or between eyelashes and limbus (dark eye case) might be no longer present in the segmented image.

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BIRD performs a binarization of the watershed transform to obtain an image where large portions of the limbus boundary are better enhanced. In this way BIRD is able to exploit the positive features of the watershed transform independently of over-segmentation problem. The boundaries of the foreground region are then inputted to a circle detection process, which aims at finding the circle that best approximates the limbus boundary (limbus circle).

To refine further the limbus boundary, the regions of the watershed transform overlapping the limbus circle are analyzed. Circle fitting [16] is then applied within the iris boundary to identify the pupil boundary (pupil circle).

The information regarding position and size of the iris (its center and radius) constitute the starting point for the delimitation of the periocular region. Recent studies [11] showed how the latter could be considered itself a biometrics. BIRD checks out the periocular region and applies to it a transformation from Cartesian to polar coordinates. In this way, it is possible to apply to the periocular area a process of extracting and matching characteristics similar to that used for the iris. Iris and the periocular region are then fused at score level through a simple sum criterion in order to increase the accuracy of the recognition system.

BIRD has been tested on a database including 1500 eye images, taken from 75 individual subjects. Eye images are the results of outdoor and indoor acquisitions, accomplished by means of three mobile devices (tablet Samsung Galaxy, Apple iPhone 5, and Samsung Galaxy S4 smartphone). Eye images in the database are rather different from each other, due to the technical features characterizing each of the three cameras and due to the uncontrolled acquisition conditions.

The rest of the paper develops as follows. Section 2 describes a pre-processing phase that improves the quality of the input eye image and reduces the computational cost of the whole process. Section 3 is concerned with computation and binarization of the watershed transform. Section 4 describes the detection of the limbus circle and the refining process adopted to fit the real limbus boundary. Circle fitting is then accomplished also for pupil detection. The segmentation of the periocular region is then addressed in Section 5. Section 6 deals with iris recognition. Section 7 regards the experimental setup. The interoperability of BIRD is also investigated by performing cross-datasets experiments. Final remarks are given in Section 8.

2. Pre-processing

Uncontrolled iris acquisition may produce an image with local distortions due for example to shadows and different color temperature. A color/illumination correction is performed to reduce such local distortions, by processing separately the three RGB components of the eye image as gray level images. For each gray level image, a Gaussian filtered version is computed. A new image is built, where each pixel is set to the ratio between the value of the homologous pixels in the gray level image and in its filtered version. This ratio has the side effect to bring out the details in the image, so the kernel parameters of adopted Gaussian filter play a fundamental role. The parameters are the kernel size g_k, the average m_k and variance σ_k (they are mainly related to the resolution of the input image). In fact, a kernel too small excessively flattens the distribution of the colors within the image, while one that is too large will not produce any substantial correction on lighting and color distortions in it. In order to find a viable relationship between Gaussian kernel parameters to be adopted and the resolution of the image, was considered a set of pictures of irises at different resolutions $w_k \times h_k$ where $k = 1, 2, \ldots, n$, $w_{k+1} > w_k$ and $h_{k+1} > h_k$. The image resolution was represented by considering the value of the diagonal $d_k = \sqrt{w_k^2 + h_k^2}$. The optimal parameters for the Gaussian kernel were determined in terms of segmentation and recognition accuracy obtained on the set of images. It was observed that the relationship between g_k and d_k is quadratic, i.e. $g_k = \alpha_2 d_k^2 + \alpha_1 d_k + \alpha_0$, while $m_k = g_k$ and $\sigma_k = 0.1 \cdot g_k$. In this case, it was found that $\alpha_2 = -0.0001$, $\alpha_1 = 0.3064$ and $\alpha_0 = 11.1351$.

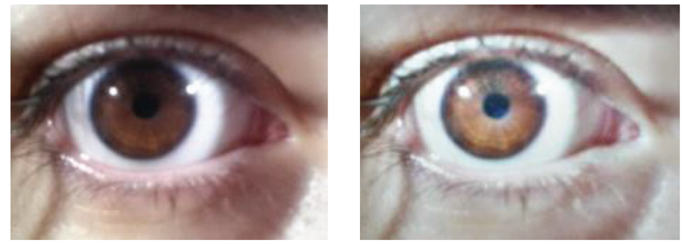

Fig. 1. An eye used as running example (left), and the result of color/illumination correction (right).

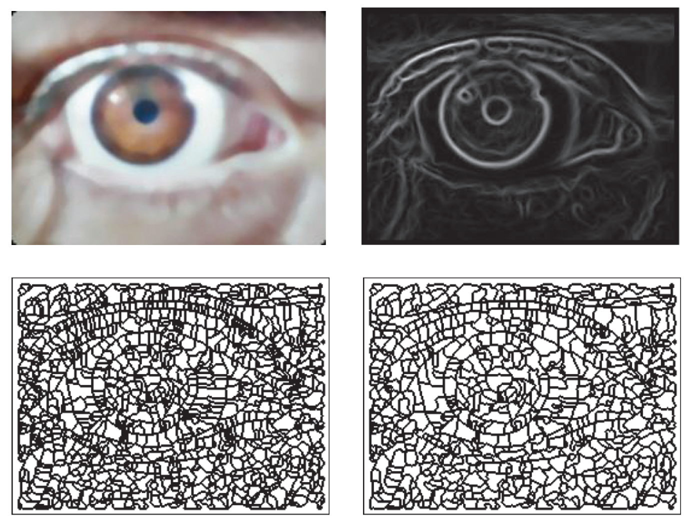

Fig. 2. From top left to bottom right: resized and smoothed image, gradient image, watershed transform, result of region merging.

A normalization process of pixel values is performed to map the values in the range [0, 255]. The combination of three obtained gray level images originates the color/illumination corrected image. The left image in Fig. 1 shows the original image, while the right one corresponds to the color/illumination corrected image. As BIRD is able to work even on low resolution images, it is possible to limit the computational cost of the method. The color/illumination corrected image is resized by using a linear interpolation method without changing the aspect ratio, in order to get an image of the eye in the foreground with a horizontal resolution of 200 pixels (vertical resolution depends on aspect ratio). As previously, the process of correcting lighting/color enhances the details in the image and these details are irrelevant for the segmentation. Thus a median filter is applied with a fixed-size window 7×7. The window size can be regarded as fixed, because the image is first brought to a standard resolution by step resizing. The resulting image I is shown in Fig. 2 top left.

3. Watershed transform and binarization

The effect of color/illumination correction is to generate an almost uniform image, independently of the acquisition conditions that are highly uncontrolled. To extract the region of interest, i.e., the iris, the watershed transformation is used to partition the image into regions, based on gradient information. As already pointed out, over-segmentation is likely to affect the obtained partition. Thus, a successive process is necessary to merge adjacent regions, characterized by a certain homogeneity. Though the watershed transformation is computationally heavy, its use significantly reduces the processing time of the remaining steps, which will involve operations to be applied