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WIRE: Watershed based iris recognition

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ABSTRACT

A Watershed transform based Iris REcognition system (WIRE) for noisy images acquired in visible wavelength is presented. Key points of the system are: the color/illumination correction pre-processing step, which is crucial for darkly pigmented irises whose albedo would be dominated by corneal specular reflections; the criteria used for the binarization of the watershed transform, leading to a preliminary segmentation which is refined by taking into account the watershed regions at least partially included in the best iris fitting circle; the introduction of a new cost function to score the circles detected as potentially delimiting limbus and pupil. The advantage offered by the high precision of WIRE in iris segmentation has a positive impact as regards the iris code, which results to be more accurately computed, so that the performance of iris recognition is also improved. To assess the performance of WIRE and to compare it with the performance of other available methods, two well known databases have been used, specifically UBIRIS version 1 session 2 and the subset of UBIRIS version 2 that has been used as training set for the international challenge NICE II.

1. Introduction

Iris recognition is one of the more commonly used biometrics. It is generally regarded as the most accurate of the commonly used biometric technologies, giving a reliable answer to the increasing demand of security systems [1]. This is due to the good features characterizing the iris of human beings (richness, uniqueness, external visibility and stability during the entire life) and to the non-invasiveness of the available iris acquisition technologies (cameras operating in the near infrared spectrum [2,3] or with visible light technology [4], able to capture good quality images at a largely variable distance (from a few centimeters up to a few meters) and even “on-the-move” [5–7]).

The literature in the field of iris detection and recognition has received a considerable number of contributions, since the first system has been suggested by Daugman [8]. A recent book, [9], providing complete coverage of the key subjects in iris recognition – from sensor acquisition to matching – and two wide surveys of iris recognition methods covering the periods until the end of 2007, [10], and from 2008 to 2010, [11], are available.

The iris is the annular part of the eye delimited by the white sclera and delimiting the pupil, which even in case of eye colors having the lightest tints of blue is the darkest part of the eye (see Fig. 2). The structure of the iris is referred to as the iris texture and has a number of characteristics significantly larger than the number of characteristics typical of other biometrics. Though an interesting debate has recently started on the stability of the iris pattern [12–14], the literature has widely shown that the probability of obtaining similar signatures from two different iris textures is close to zero [1]. Thus, at least under nearly ideal image acquisition conditions (good illumination and cooperative subject), simple image processing tools can be satisfactorily adopted for iris recognition. In turn, under non-ideal conditions, problems such as occlusions caused by eyelids and eyelashes, poor illumination, specular reflection and lack of cooperation of the subject whose identity should be detected, make iris recognition a hard task to face.

The main weakness of iris recognition techniques developed in the last years is that they show a proven effectiveness only in relatively constrained scenarios, performing in the near infrared spectrum and at close acquisition distances. So recently, several researchers have focused their attention on designing a novel family of iris segmentation algorithms operating on images acquired in less constrained conditions and under the visible light. However, the unconstrained iris image acquisition introduces additional noise factors as reflections, blurring and defocus, mainly

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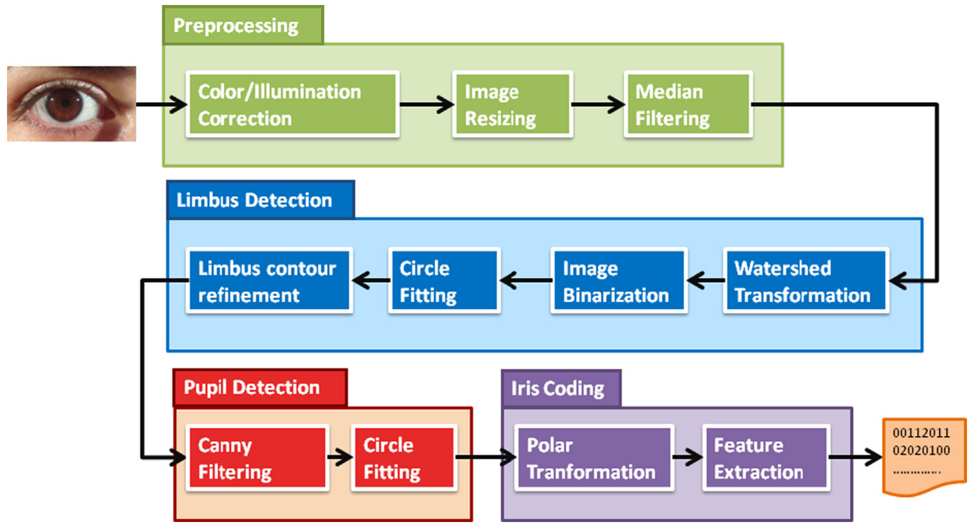

Fig. 1. Flow chart of WIRE.

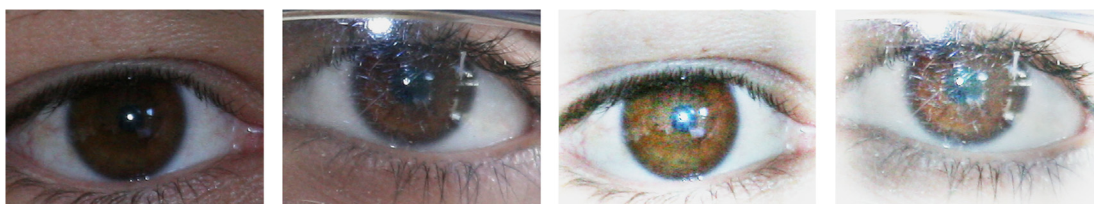

Fig. 2. Images of two subjects from the UBIRIS2t dataset, acquired in uncontrolled environment under different illumination conditions before (left and middle left) and after (middle right and right) the color/illumination correction. (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

due to subjects moving at widely varying distances. To solve the problem of the detection and recognition of heavily degraded iris images, the scientific community promoted two international evaluation initiatives about these issues, named Noisy Iris Challenge Evaluation (NICE) [7]. This competition was divided in two parts: (i) Part I – for the segmentation of iris images in visible wavelength and (ii) Part II– for the recognition of iris images in visible light.

Iris recognition includes a number of processes: (i) acquisition of the eye image, (ii) iris segmentation, to separate the foreground (iris and pupil) from the background (the rest of the image), (iii) normalization, to produce iris regions with the same constant dimensions, so that images of the same iris taken under different conditions have their features at the same spatial locations, (iv) features extraction, to associate a code to each detected iris, and (v) recognition, generally accomplished by using mathematical and statistical algorithms to compare the code of the iris at hand with the codes stored in a suitable database. All processes (i)–(v) should be accomplished in accurate way, since the result at each step conditions the outcome of the successive step.

Though this paper introduces the iris recognition system WIRE and, hence, deals with all the above processes, in what follows we will focus mainly on the novel contribution of this paper, i.e., on iris segmentation for degraded iris images acquired in visible wavelength. Iris segmentation is obtained by using both watershed transformation and circle fitting. In this way, we identify the iris boundary more precisely than by resorting only to circle fitting, and obtain an accurately computed iris code. Using the watershed transform is important since the shape of the iris is not necessarily circular and because pixels inside the best fitting circle may be noisy iris pixels. To assess the performance of WIRE, we adopt two well known databases: UBIRIS version 1 session 2 (UBIRISv1s2) [15] and the subset of UBIRIS version 2 that has been used as training set in NICE (UBIRISv2t) [16].

The rest of the paper is organized as follows. Previous work for iris segmentation is briefly reviewed in Section 2. The segmentation scheme of the proposed system WIRE for watershed based iris recognition is described in Section 3. Section 4 deals with iris recognition. Section 5 discusses parameter setting. Section 6 is devoted to the experiments and to the discussion of the obtained results. Concluding remarks and some ideas for future work are finally given in Section 7.

2. Related works on iris segmentation

The role of iris segmentation is to identify in the image of the eye all pixels belonging to the iris. Note that pixels in positions where iris pixels are expected may be noisy pixels and should not contribute to the computation of the iris code. Segmentation is a crucial task since inaccuracy in iris detection has a strong negative impact on the performance of the whole recognition task.

Iris segmentation is generally achieved by identifying the boundary of the pupil and of the limbus, so as to delimit the region of interest in the image, and by suitably taking into account that eyelids and eyelashes may overlap with the iris causing interruptions of its boundary.

Methods for iris segmentation can be roughly divided into two categories: (i) methods approximating the iris boundary with a circle or an ellipse, and (ii) methods determining the precise boundary of the iris. Methods in the former category are often referred to as classical methods.

A well known classical method employs the integro-differential operator [3]. The input image is preliminarily convolved with a Gaussian filter to obtain a smoothed image. In this way, noise is reduced without affecting the strongest edges, i.e., those in correspondence with the boundaries of iris and eyelids. Then, by means of an integro-differential operator, the maximum value of a