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Frame detection using gradients fuzzy logic and morphological processing for distant color eye images in an intelligent iris recognition system

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ABSTRACT

The capture of an eye image with the occlusion of spectacles in a non-cooperative environment compromises the accuracy in identifying a person in an iris recognition system. This is due to the obstruction of the iris by the frame which tends to produce an incorrect estimation of the initial center of the iris and the pupil during the iris segmentation process. In addition, it also causes incorrect localization of the upper eyelid during the process of iris segmentation and sometimes, the edges of the frame are wrongly identified as the edges of the upper eyelid. A frame detection method which involves the combination of two gradients, namely the Sobel operator and high pass filter, followed by fuzzy logic and the dilation operation of morphological processing is proposed to identify the frame on the basis of different frame factors in the capture of a distant eye image. In addition, a different color space is applied and only a single channel is used for the process of frame detection. The proposed frame detection method provides the highest frame detection rate compared to the other methods, with a detection rate of more than 80.0%. For the accuracy of the iris localization, upper eyelid localization and iris recognition system, the proposed method gives more than 96.5% accuracy compared to the other methods. The index of decidability showed that the proposed method gives more than 2.35 index compared to the existing methods.

1. Introduction

Current studies on the iris recognition system show that the eye images were captured without the cooperation of the person, at different distances and in motion (also known as non-cooperative environment) in order to make the system more accurate and reliable in identifying and verifying a person in a real environment [15,28]. For this reason, the captured eye image has very low quality [26], varying lighting conditions [27,35] and contains a noise factor such as the occlusion of spectacles [14,17,20,28,33]. Spectacles (also known as eyeglasses) are defined as a frame that contains lenses, which are normally used for vision correction [20], eye protection [19] and esthetics or fashion purposes [5,18]. Several studies have shown that, in certain circumstances, wearing spectacles could have a negative impact on the performance of human–computer interaction systems such as driver-fatigue detection systems [5], face recognition systems [4] and iris recognition systems [28]. It is crucial to detect or remove the spectacles from a captured image to increase the performance of systems, and several studies [11,43,44] have been conducted for this purpose except in the case of the iris recognition system. The occlusion of spectacles in the eye image has caused several problems in the iris segmentation performance such as the existence of reflections and incorrect iris and eyelid localizations. The existence of reflections from the lenses (see Fig. 1a) has caused the incorrect localization of iris boundaries due to the edges of reflections being wrongly detected as the edges of the iris boundaries. Thus, several researchers [3,14,31,34,41] have proposed reflection detection and removal methods in order to solve this problem. During the process of iris segmentation, the obstruction of the iris by the frame (see Fig. 1b) tends to produce an incorrect estimation of the initial center of the iris and the pupil [3,14]. Thus, it leads to incorrect iris boundary localization. It can also cause incorrect localization of the eyelid, specifically in the upper region due to the upper region being obstructed by the frame (see Fig. 1c) and the edges of the frame being falsely recognized as the edges of the upper eyelid. The degradation of iris segmentation performance has caused errors in the iris feature selection due to the frame being wrongly extracted as the iris features, thus, reducing the accuracy of current iris recognition systems.

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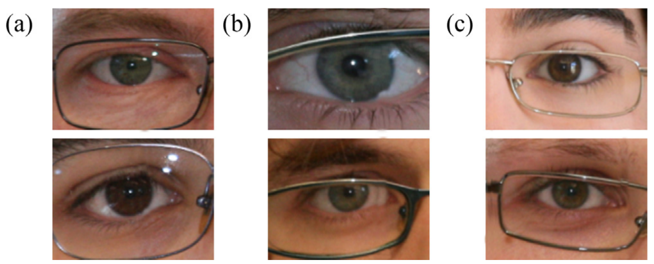

Fig. 1. Problems existed in the eye image due to the occlusion of spectacles. (a) Existence of reflections in lenses. (b) Iris obstructed by frame. (c) Upper eyelid obstructed by frame.

Several methods have been proposed to solve the problems existing for frames in human–computer interaction systems. These can be divided into detection and removal approaches. For example, in a driver-fatigue detection system, Cheng et al. [6] used a binarization based method, with a threshold of 40, to detect the frame and implement a dilation operation and skin color model to extend and remove the frame. They concluded that their method is good for detecting and removing the frame if the image was captured in a laboratory environment. However, they suggested an adaptive thresholding method to detect the frame in the real environment. In the face recognition system, Wang et al. [43] implemented an adaptive thresholding method and a reconstruction based method involving iterative principal component analysis to detect and remove the frame from the face images. Wong and Zhao [44] also applied a reconstruction based method involving kernel principal component analysis to remove the frame from the face images. A disadvantage of using the reconstruction based method is that it requires large datasets that contain images with and without spectacles. In addition, sufficient information or additional knowledge is essential for reconstructing the extracted spectacle region [44]. In iris recognition systems, several researchers have claimed that their iris segmentation methods succeeded in localizing the iris even with the presence of spectacles. For example, Sahmoud and Abuhaiba [33] proposed the K-means clustering algorithm and circular Hough transform to determine the iris region and compute the iris center and radius. Then, the upper eyelid is localized using the intensity difference between the sclera and the upper eyelid in the sclera region rather than in the iris region because the contrast intensity between the iris and the upper eyelid is low. Tan et al. [41] assumed that the frame is usually dark in color and approximately rectangle shape. To localize the iris, they introduced a clustering based coarse and integrodifferential constellation; while to localize the eyelids, the one dimensional horizontal rank filter and eyelid curvature model are implemented.

Even though several existing iris segmentation methods are able to localize the iris boundaries in the presence of spectacles, the problem remains open due to several frame factors. Firstly, the color of the frame is not usually dark in color; rather, according to Chen et al. [5], the frame color can be categorized into three types, namely: dark, medium and light. Secondly, the shape of the frame does not always approximate a rectangular shape [18], nor is the frame usually in a complete form when captured in non-cooperative environments. The frame shape in non-cooperative environments can be divided into five symmetrical types: (i) full (consists of rectangle and circular shapes), (ii) horizontal, (iii) vertical, (iv) diagonal and (v) undefined. Thirdly, the types of frame can be categorized into full-frame, half-frame and no-frame [18]. Lastly, the thickness of the frame can be classified as thick or thin. The frame factors are summarized in Table 1. Hence, a method that is capable of resolving these factors is needed in order to increase the performance of iris segmentation for the eye images with the occlusion of frames.

In this study, two gradients (namely, the Sobel operator [42] and high pass filter [24]), a fuzzy logic [12] and the dilation operation of morphological processing [38] are proposed to identify the frame in distant color eye images in an iris recognition system. The gradients are able to provide the information on the frame edges, the fuzzy logic is performed as the decision making for frame detection and the dilation operation of morphological processing functions to fill the discontinuity edges of the frame. This method is able to extract the edges of the frame from different factors and its performance is better than the existing frame detection methods. The process of frame detection starts with converting the color image into a different color space which is the hue-saturation-value (HSV). Next, each gradient is defined using the appropriate membership function and then the fuzzy inference system is applied based on the inference rules. Lastly, the dilation operation is used to fill the gap in the edges of frame. To explain the proposed method in detail, this paper is structured as follows: Section 2 describes the selection of the database for the bespectacled eye images, namely UBIRIS.v2, Section 3 explicates the proposed frame detection method, Section 4 describes the iris recognition system methods, Section 5 discusses the experimental results and lastly, Section 6 states the conclusions and suggestions for future work.

2. Bespectacled eye images

Two databases [10] containing distant eye images are available for iris recognition purposes, namely version four of the Institute of Automation, Chinese Academy of Sciences database (CASIA.v4-Distance) [40] and version two of the University of Beira Interior database (UBIRIS.v2) [28]. During the process of image acquisition, the eye images in the CAISA.v4-Distance were captured using near-infrared wavelength illumination at distances of 3 m while the eye images in UBIRIS.v2 were captured using visible wavelength illumination with distances of 4–8 m, with motion and under lighting variations. According to Proenca and Santos [25], Shin et al. [36] and Proenca et al. [28], the use of the near-infrared wavelength to capture the distant eye images requires a high level of illumination which could threaten eye safety during the process of acquisition. Moreover, the visible image provides more information than the near-infrared image [32]. The UBIRIS.v2 database was chosen for this study because the eye images in this database has meet the study's requirements, that is, the eye images were acquired at long-range distances, in motion and using visible wavelength illumination. In addition, the eye images in the UBIRIS.v2 database contain more realistic noise factors such as low illumination [29], reflections [3,14,31,34,40], off-focus [37], off-angle [39] and the occlusion of spectacles compared to the eye images in the CASIA.v4-Distance database.

The performance of the frame detection and iris recognition system methods was evaluated using approximately 500 bespectacled eye images with less than 30° angles. This was done to avoid inaccurate iris segmentation or decreased of iris recognition system accuracy due to less extracted iris area from the eye images with more than 30° angle. The bespectacled eye images were divided according to different frame factors and distances, with each distance consisting of 100 bespectacled eye images as shown in Table 2. However, eye images with the occlusion of medium color and half-frame spectacles, and light color and half-frame spectacles were not available in the UBIRIS.v2 database. In addition, some of the eye images did not contain frames due to the eye images being captured at a very close distance of 4 m. For example, at 4 m, the eye images included dark, half-frame and thick factors, or light, full-frame and thick frame factors.

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