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Robust method for Gaze Recognition Using Histogram Thresholding and Neural Network

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Abstract

The existing studies discuss an effective method for individual's gaze recognition in unconstrained environments. In first step, coordinates of pupil center have been calculated for gaze recognition. In suggested method and algorithms, firstly, pupil center have been localized by histogram Threshold and Average Filter. Some steps of algorithms have been optimized in the purpose of reducing complexity, performance optimization, and increasing the speed of algorithms. At first, by applying the method of Connected Component Analysis, the pupil center and then the peripheral circle of the edge point of pupil and Iris have been localized. Datasets MMU1, MMU2, and UBIRIS3 have been utilized for testing this method. In next step, data classification in gaze recognition system is performed by applying multilayer neural network and the Learning algorithm of back-propagation of errors .For testing suggested method, around 234 images of Colombia Gaze Datasets have been used. The performance of this method for our mentioned dataset is calculated and our final result is 88%.

Keywords: *Gaze recognition, histogram thresholding , Average filter , neural network , Back- propagation .*

1. Introduction

Gaze recognition is assumed as a none-speech cohabitation, which indicates reaction with environments. So gaze recognition would be one of key elements for conveying new reactive model. Gaze recognition is defined as a main concept in modern society, where in some cases, human operators (such as pilots and surgeons) apply it for performing various activities , but acquiring this ability and skill affected on our modern techniques and technology.

Applied purposes of gaze recognition are described as below:

medical activity[1] computer game controlling [2], robotics [3] recognizing driver's fatigue for avoiding most road accidents[4]. There are some challenges for gaze recognition, which in some images, it would be possible we see a bit rotation in heads of individuals, conditions of image-making (resolution and your distance to camera) to be various in all images and some people wear glasses and etc.[5].

All above-mentioned points make the process of gaze recognition a bit difficult, which face detection has been assumed as a favorite subject for researchers in psychology and in engineering sciences and image-processing in last 15 years.

A formal method for first time is suggested by Francis Galton in 1888. This method collects face characteristics and then our mentioned features are exploited. There are more than 100 various methods for face detection. One of our favored activities is performed by Yang & Howang in this field[6]. Another recognition method is delivered by Armitt Sharma, which is known one of weak methods[7]. For face detection, the mostly-used algorithm is Viola Jones. And face area is separated by a rectangle framework from other consisted parts of image[8]. Color features have been applied for face detection and binary image is made and histogram calculation is performed [9] and face is recognized due to color characteristics and by applying neural network, face is detected[10]. Some researchers utilized Gabor Filter for face detection, where preprocessing is done for optimizing image quality and then Gaze Gabor Filter is performed on it[11,12].

In the purpose of gaze recognition, some researchers, at first, studies eye features. For detecting eye area, there are several methods .one of these methods is Ring Gabor Filter, which initially detects face area and then the eye detection process is performed[13,14]. The color features is another algorithm of recognizing eye location. In this algorithm, morphology operation has been selected[15]. After determining eye, some researchers have done some

projects for separating left-side eye and right-side eye from each other, where they can speed up the gaze recognition[16]. In most cases, firstly, face and eye should be detected for recognizing person's gaze. also, in this process, iris is studied and the after reading iris image, the edge points of pupils, iris and pupil center are detected. Also eyelashes and eyelids are omitted from eye area[17]. Some studies have been done for pupil extraction by the method of OTSU threshold, which pupil localization is performed after pupil extraction and noise deletion[18]. Hough Transform is another technique for pupil localization, which is mostly-used method among other gaze detection method and when eye has spherical form, Hough transform recognize pupil's sphere very well[19].
Radial symmetry Transform is another technique for detecting pupil center, where is defined as a complete usage of gray information and features of Radial Symmetry of pupil[20].
The Ridge lets technique is another algorithm for detecting iris, which is more suitable for detecting lines[21].
After recognizing face with color feature, eye is detected by horizontal and vertical images[22, 23, 24].
The remainder of this study is organized in the same way. In 2nd section, proposed method is analyzed. In 3rd section, test method on many datasets of images is studied and then in 4th section, the conclusion process is performed.

2. Suggested method

At first step, pupil location should be detected in the purpose of gaze recognition. In this study , a combination of histogram threshold technique[32] and neural network have been applied. Fig 2-1 shows the diagram of proposed algorithm.

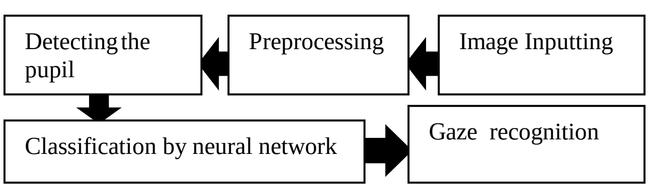

Figure 2-1 Block diagram of the proposed method.

2.1. Image Inputting

In this step, image is read on entry and then entered into the system. The input image can localized on saving tools or you can take it via camera. For example, by taking an image from eye in identity recognition system, input image of system is appeared[33]. In this paper, available datasets have been utilized for preparing eye's images.

2.2. Preprocessing

The total goals of this step can be based on image optimization and deletion of unnecessary elements of images. These points should be omitted before image processing by all methods of image-processing.

2.3. Detecting the pupil of eye

This process of image-processing can be known for its several steps, where details of this algorithms are described in remainder of this section and pupil eye is detected by histogram threshold and then some deletions are performed for optimizing.

2.4. Classification by neural network

In previous steps of pupil recognition, deletion process and necessary optimization are performed. In this step, neural network have been utilized for determining gaze recognition[25,26,27,28].

2.5. Suggested method

At first, one image of eye should be selected, where images of MMU1 and MMU2 datasets[29] have been applied in this study. The size of images is 320*240 pixel and transformed into Gray image. Optimization method is selected when there is unsuitable image in Contrast Method and the threshold process is performed. Then eye image is divided into 3 resolution area as fellow: Lower, middle, upper areas. Lower areas, including pupil and eyelids, have more dark resolution .Middle area, including iris and eyelids have medium resolution. Upper area , including sclerotic coat, have more resolutions. So detecting eye pupil in lower area can be a bit difficult. After first threshold, sclerotic coat and skin are omitted. And for deleting unnecessary area like eyelids and eyebrows, the Average Filter and Open morphology technique are applied. This method consists of several steps. Some of these steps , including sub- categories, which in details are described in next section. Then some steps have been deleted in order to speed up and to reduce algorithm complexity. We have spent our attention to gaze attention subject by applying neural network.

2.6. Proposed Algorithm

In this step, an image should be selected as a input image. Colored image is transformed into gray image. If our mentioned image is gray, we apply the same process. For selecting some images, available images of MMU1 and MMU2 have been used. Figure 2-2(a) shows histogram graph of initial image of MMU2 dataset with acceptable

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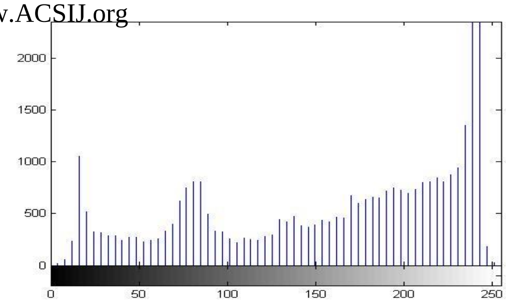
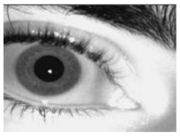
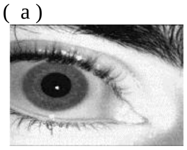


Histogram graph (a)



Optimized image (c)



Input image (b)

and good contrast. In next step, image optimization is performed .Figure 2-2(c) indicates optimized image.

Figure 2-2:Image optimization

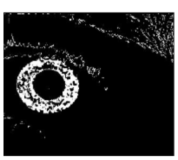
In next step, minimum value of optimized image is zero(0) and its maximum value is 255. We can gain threshold value by adding minimum value to maximize value. Then we divide the total value in 2 in areas with values higher than 127.5, the resolution value became zero (0). The rest protect their values. Skinny area and white areas are deleted and you can obtain new gray image. (Figure 2-3(a)).

The maximum value and minimum value became 127.5 and zero respectively. And you can earn the value 63.5 as a threshold value (new) by dividing combination of minimum and maximum values on 2(Eq. 2).

You can see more resolution in these areas. Areas with lower than 63.5 refer to pupil area. Areas with value higher than 63.5 refers to iris area (Figure 2-3(c)).

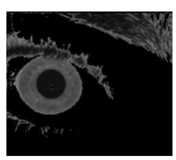
$$\text{threshold} = \text{max value} + \text{min value} / 2 \qquad (1)$$

$$\text{threshold} = \text{new maximum value} + \text{new minimum value} / 2 \qquad (2)$$



pupil (c)

iris (b)



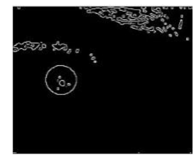
Binary image (a)

Figure 2-3: Detecting iris and pupil

In resulted image from figure 2-3(b) , the lower area shows pupil area. So we can recognize the edge point of pupil by applied algorithms for deleting the edge of pupil, where the Canny detector is more robust than other detectors. So we utilize Canny detector for recognizing the edge of pupil. In this step, unwanted areas are highlighted clearly by the Average Filter and the Open morphology techniques. In average filter, the value of each pixel in output image is as the same as the average value of resolution intensity. For current pixel, neighbor pixels are assumed as a current pixel, where for making the quiet image and for deleting noises with high frequencies, it is applied. constrained connection of image are deleted for making quiet image by the open morphology on binary images and the we can have quiet image (figure 2.4).

(a)

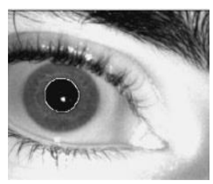
(b)



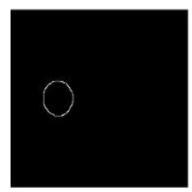
(c)

Figure2-4: detecting unwanted areas

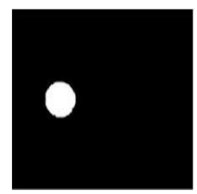
In this stage, the results of two previous steps are compared in order to extract pupil area, so its comparison means that an intellectual relation between two images is made and then Imfill order is applied and holes are filled up. Resulted image is according to figure 2-5(a).the edge is highlighted and recognized by detector for recognized area in previous step. After recognizing the edge points of pupil in figure 2-5(b) by detector, all processes are performed in original image and the pupil area is recognized in original image. All results are shown in figure 2-5.



(a)



(b)



(c)

Figure2-5: detecting and recognizing pupil area.

For performance optimization and for speed up our mentioned algorithm, and for reducing the complexity of proposed algorithm, a robust solution is introduced In previous algorithm, which including initial steps of algorithm and details of this algorithm are described in the remainder of this section. And these steps can destroy the deleted speed.

For algorithm optimization:

1-first, an image is selected for gaze detection

2-Input image is selected for gaze detection

3-the process of image threshold is performed and binary image is resulted.

For resulted image in stage3, the minimum and maximum values are calculated, where maximum value would be 127.5 and minimum value would be zero and their average is calculated as a new threshold level (Eq. 3). New threshold in value 42 is resulted by dividing the total amount of maximum and minimum values on 3(Eq.4). pixels with resolution lower than this threshold is mentioned as a down area and pixels with resolution higher than this level is known as upper area. Totally, we can have better results. In this step , we have studied two upper areas Upper area, which refers to zones higher than 42 and lower area refers to zones which is lower than 42 , where it is resulted in previous stage. And we select our mentioned resolution, which have more similar repetition in this two areas. In this step, determined resolution in previous stage (resolution in upper & lower areas)and its peripheral resolution are selected separately. when resolution is determined in this step, pupil area is recognized by this resolution.

$$\text{threshold} = \text{maximum value minimum value} / 2 \tag{3}$$

$$\text{New threshold new} = \text{maximum value} + \text{new minimum value} / 3 \tag{4}$$

New stage is taken all characteristic of objects for available objects on pupil image by connected component analysis graphs of peripheral object method, where area features convey the number of pixels in objects. And rectangle feature convey peripheral graph of rectangle object and after this analysis, we recognize a pixel which have more pixel. And when this object is found, it is selected as pupil. The coordinates of peripheral chart are extracted and by having coordinates of surrounding chart, the radius of peripheral circle can be drawn with its center, where output image would be according to figure 2-6.

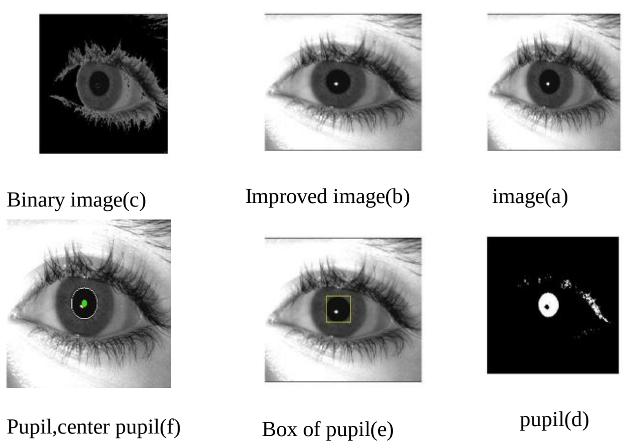


Figure 2-6: complete execute for optimized algorithms on dataset MMU2 for pupil detection

3. Test Method

Initial algorithm has been tested on 150 images of MMU1 and MMU2 datasets. Number of true images is rare and false and incorrect images are a lot. (figure 3-2 , figure 3-3, figure 3-4 , figure 3-5, figure 3-6 and figure 3-7). Our mentioned algorithm is not able at all to detect pupil on dataset Ubiris 3[30].

After optimizing our mentioned method, the figure 3-8 ,the accuracy in dataset MMU1 reach to 100% and in dataset MMU2 among 150 tested images ,only 20 images are not able to detect pupil (figure 3-9).

In dataset Ubiris3 , also , many images are able to detect pupil (figure 3-10) By applying 234 images of Colombia Gaze dataset [31], 10 neurons in hidden layer is applied and eye image is transformed into size 4*6.

And 24 images with two coordinates on center of pupil are entered into neural networks. In table 3-1 and in table 3-2, number of true images, false image after and before algorithm optimization have been transmitted on datasets.

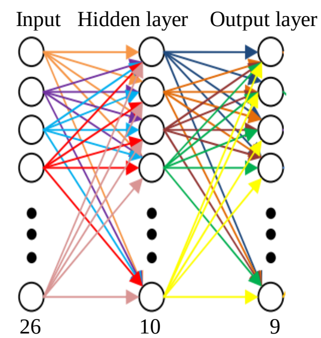


Figure3-1 neural network

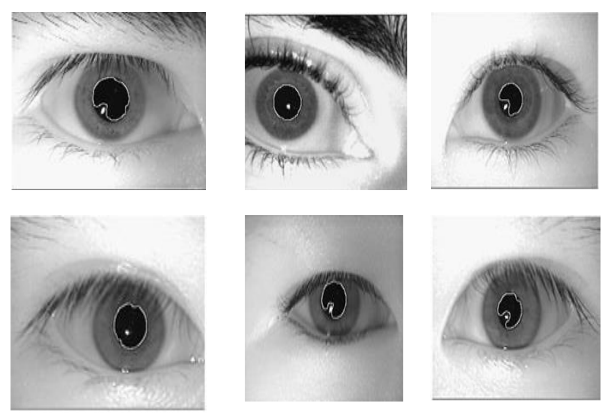


Figure 3-2 Correct images MMU1 database

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Figure 3-3 Incomplete images MMU1 database

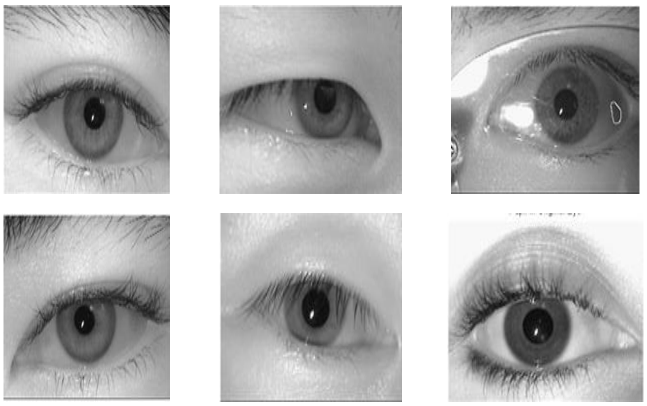

Figure 3-4 Wrong images MMU1database

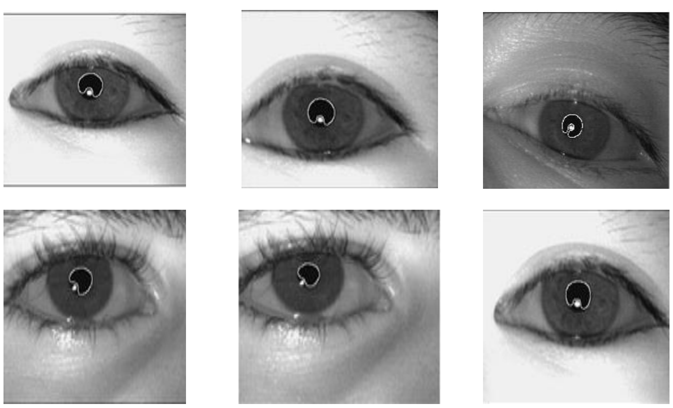

Figure 3-5 Correct images MMU2 database

Figure 3-6 Incomplete images MMU2 database

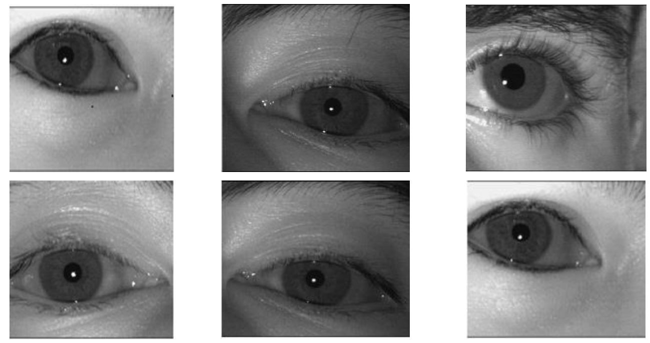

Figure 3-7 Wrong images MMU2 database

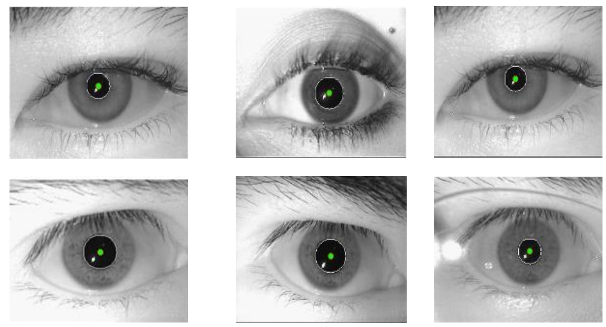

Figure 3-8 Improved algorithm images on the MMU1 database

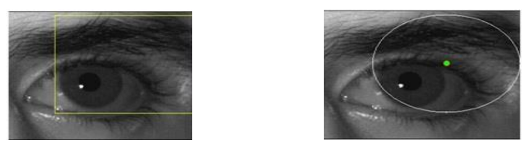

Figure 3-9 Wrong image MMU2 database

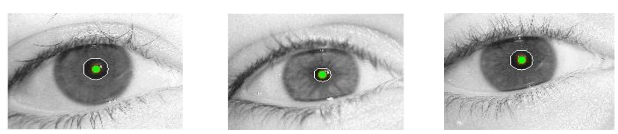

Figure 3-10 Correct images Ubiris3 database

Table 3-1 Before algorithm optimization

incomplete	***correct***	***false***	***images***	***dataset***
66	76	8	150	***MMU1***
24	81	45	150	***MMU2***

Table 3-2 After algorithm optimization

imcomplete	***correct***	***false***	***images***	***dataset***
-	150	-	150	***MMU1***
-	130	20	150	***MMU2***
-	14	6	20	***UBIRIS3***

4. Conclusion

In this paper, Gaze recognition obtained histogram thresholding combination of neural networks and the accuracy of the proposed method was 88%. Indicating this method is very high accuracy. In the future, if the construction of high quality database for Gaze recognition accuracy of the proposed method on it will be 100%. There are proposals to Gaze recognition the robot to be made to Gaze recognition. The proposed method is applied on the corner of the eye and 28 specific input into the neural network. For Gaze recognition to be more accurately**.**

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