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RESEARCH ON NON-INVASIVE EYE TRACKING USING CORNEAL REFLEX

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ABSTRACT

As the existed eye tracking devices are so complex that the restrictions on the position are too many and people have to wear special equipment, this paper introduces a novel method against eye tracking: using the five near-infrared light as the source of corneal reflex. With the help of our method, people won't need any equipment against eye tracking. Our method is able to adapt to the natural head movement and calculate the position of sight more accurately. In order to improve the mapping accuracy, a new method for pupil edge fitting is proposed to fit circularly and remove false points. In our paper the grayscale of images is used to initialize eye position quickly and accurately. Besides, we introduce the theory of cross-ratio invariance to make coordinate mapping and calculate the attention coordinate accurately.

Keywords: *Eye Tracking; Corneal Reflex; Pupil Edge Fitting; Cross-Ratio.*

1. INTRODUCTION

Movement detecting and tracking[1] is an important research area in computer vision[2]. It has popular application future especially in real-time monitoring and investigating. Through summarizing and improving some existed algorithms, we put forward a novel method against eye tracking.

At present, the research to make active eye tracking[3] in complex background is classified into three classes: the first one is completely based on moving information in images for target tracking[4-5], the second one is based on the image information and complemented by the moving state of video[6-7], and the third one is to use priori knowledge of object models for tracking some objects of them[8-9]. All the three classes of methods mentioned above have something in common that movement models should be constructed based on some hypotheses and movement parameters are gained based on light flow equations.

This paper puts forward a non-invasive eye tracking technology based on corneal reflex [10]. This method does not need any wearing equipment, and can adapt to the natural head movement. The algorithm designed by this paper calculates the position of sight in high accuracy.

The rest of this paper is organized as follows: Section 2 provides an eye tracking scheme including ROI looking for the ROI and light spot coordinate calculation. Section 3 discusses the experiment and analyzes the results. We conclude in Section 5 and offer an overview of our ongoing and future work.

2. EYE TRACKING SCHEME

2.1 Looking For ROI

The foundation of the below work is to extract eye features quickly. In order to address the problem, a new fast detection method is introduced on the basis of experiments.

There are different reflectivity and refractive index to infrared light for different areas of an eye. In all the areas of an eye, the pupil's reflections in the infrared light are weakest. It is why the pupil is black in infrared light, while other areas are not. Based on the above observation, we can quickly and accurately fix the eye position efficiently.

We can adopt classic threshold technology [11] to process gray image. Making the use of all the points which are less than threshold value (xi, yi) (i=1…n) to rough fix pupil centre position in the binary image:

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$$x_{pupil} = \frac{1}{N}\sum_{n=1}^{N} x_n \quad (1)$$

$$y_{pupil} = \frac{1}{N}\sum_{n=1}^{N} y_n \quad (2)$$

According to the rough position pupil centre, we can set the 60*60 pixels rectangular region which center around the pupil centre to be ROI. Then we can narrow the range of image processing and only operate on the areas of interest to improve image processing efficiency.

2.2 Light Spot Coordinate Calculation

If we want to calculate the accurate gaze point location, we have to get five light spot coordinate s of corneal reflex in the infrared lamp. Due to the effect of image noise and head movement, the light spot intensity might be instability. The light spot could be a little dark, sometimes. It is more difficult to trace the light spot. Therefore we propose a quick method to extract light spot.

Firstly, we divide images according to experienced threshold. We can use proper threshold processing to get light spot information.

Secondly, we use mass center method to calculate their central coordinate; at the same time, we can use the relative position of light spot to detect and eliminate false light spot information.

Thirdly, if there is no light spot at all, we can use the light spot coordinate that is found to forecast the missing one as while as decreasing threshold and searching the missing light spot in the prediction region. It will not stop until we find the light spot.

The calculated light spot is in Figure 1 below.

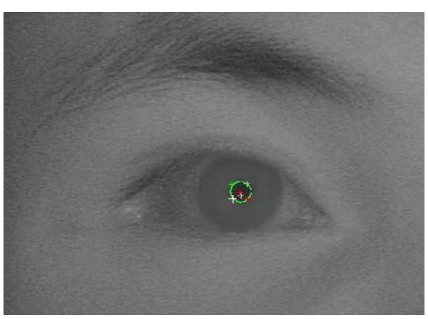

Figure 1 Light Spot Coordinate Calculation

3. EXPERIMENT AND ANALYSIS

This research implements a vision controlling mouse system. Figure 2 is the real system representation.

This system is designed by visual C++ in windows XP. After the system's implementation, it is tested in general office environment. People sit before the computer in a normal computer operation habit. The screen's size is 17-inch and the screen's resolution is 1280×1024 pixels. The viewpoints can be demarcated through 49 ticks on the screen. The screen can display the actual results of the location that eyes gaze at. Besides, if the location is within the a tick's center's 200*120 pixels area, and click the mouse on site, then this area will response in a button form and produce a flash. We extract the characteristic parameters of different testers first, characteristic parameters are checked and process the vision location experiment.

Figure 2 Real System Representation

3.1 Checking Experiment

The result of experiment of five testers is as following in Figure 3.

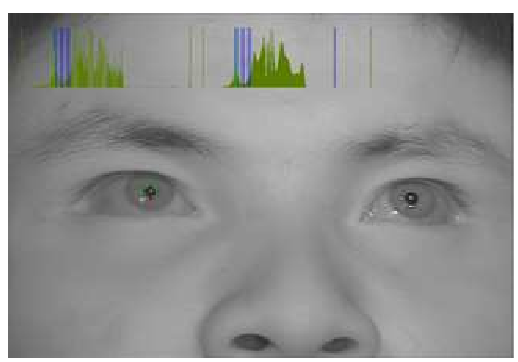

Figure 3 Spots Calculation

For every tester, firstly the image is processed and five light spots are obtained. Secondly, the location of light spots will be appointed clearly in order to ensure the light spots' acquisition correctly.

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Thirdly, the cross-ratio [12] invariance is used to calculate the value α.

There is no difference of the value α between different people. The tiny variation can lead to a large influence on the mapping process. In the collection process, in order to calculate the value of α accurately, the tester should gaze at the light source for at least 20 seconds. Different testers use screens of different heights and widths. The four α values and two calculation parameters on screen affect the result together.

Table 1. Result Of Verify Experiment

Persons	Alpha1	Alpha2	Alpha3	Alpha4	Height	width
1	1.2881	1.3382	1.2896	0.9159	1250	1400
2	1.2778	1.4142	1.3992	1.0735	1324	1400
3	1.1862	1.1906	1.1804	1.1169	1464	1280
4	1.3444	1.2200	1.0334	1.2798	1350	1350
5	1.2310	1.2400	0.9800	1.1570	1280	1024
6	1.2381	1.2635	1.2463	0.9535	1240	1400
7	1.2748	1.4145	1.4902	1.1235	1364	1400
8	1.1862	1.1866	1.1564	1.1158	1445	1280
9	1.3354	1.2450	1.1034	1.2798	1507	1350
10	1.2571	1.2359	0.9635	1.1120	1309	1024

3.2. Vision Location Experiment

The viewpoints can be demarcated through 49 ticks on the screen. The screen can display the actual results of the location that eyes gaze at. The actual result of experiment can be displayed by the pointer of mouse. We can check the accuracy of the experiment by seeing the difference between the actual gazing point and the tick's coordinate.

Using random elliptic fitting pupil edge method and Kalman filter method to locate the view, the result is followed in Figure 4:

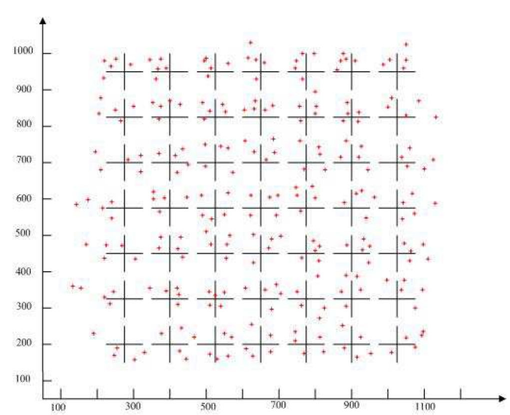

Figure 4 Result Of Traditional Method

The big ticks in the image represent the true location that tester gaze at while the small ticks represent the true result. The traditional experiment shows that this method can be used to locate the view, but the error is big.

Figure.5 Result of traditional method

This research's view location result is followed in Figure5:

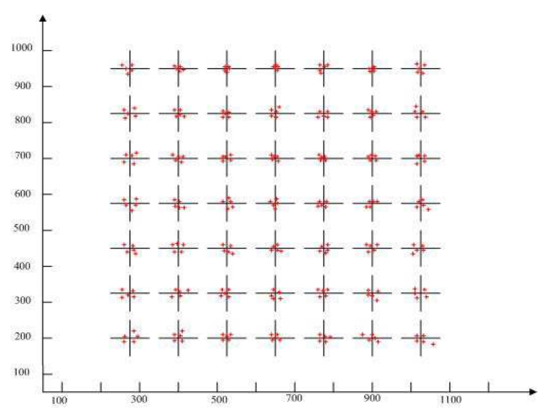

Figure 5 Result Of This Method

We can see the result has a obvious promotion from the Figure 7. This research's result is more close to the actual gazing point though the result can't coincide with the actual gazing point. On the precision it is improving much compared with the traditional method.

From the button response experiment, we can see that this method improves the precision of the location a lot. The effective data improves 40% compared with the traditional method. On the one side it shows that the precision improves, on the

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other side it shows the stability of gazing point improves.

The head can move freely in the area that CCD video camera can capture. The head's movement has little influence on the result. It has the best result when the head faces the screen straightly and the distance between the head and screen is 50-80CM. Besides the nearer the gazing point approaches the screen center, the more accurate the location's coordinate is. Every square button's location is precise. But the left side and right side may be less precise than the center.

The experiment result proves that using the cycling elliptic fitting method to extract the pupil's edge and reject the false points to get accurate position of pupil center. It improves a lot compared with the traditional method. Using cross-radio to map is more precise than Kalman filter method.

4. CONCLUSION

This research puts forward a new eye tracking technology. This method does not need any wearing equipment and reduces the limitation to users. A new method of pupil edge fitting is put forward to fit circularly and remove false points to get accurate position of pupil center in order to improve mapping accuracy. Compared with the current research, this research is more accurate. This research can be applied to every aspect of human-computer interaction and it has broad application prospect.

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