Vision-Based Eyes-Gaze Detection Using Two-Eyes Displacement

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Abstract: One problem of vision-based eye-gazed detection is that it gives low resolution. Base on the displacement of the eyes, we proposed method for vision-based eye-gaze detection. While looking at difference positions on the screen, the distance of the centers of the eyes change accordingly. This relationship is derived and used to map the displacement to the distance in the screen. The experiments are performed to measure the accuracy and resolution to verify the proposed method. The results shown the accuracy of the screen mapping function for the horizontal plane are 76.47 % and the error of this function be 23.53%

1.Introduction

There are many patients who are not of body movements and can nor communicate well with other people by any other means but their eyes. This group of people is one example of the applications the eye-gaze detection technology by which patients can gaze into a screen to select a choice from a menu. Another application of the eye-gaze detection is to use it as input device for computer games, security systems, etc.

Eye-gaze can be divided into two groups, namely infrared-based approach [1-3] and vision-based [4-5] approach, regarding to the light sources. The key advantage of the infrared-based approach is that the information is clearer, but it is difficult to control the light sources. On the other hand, by using the images from the normal cameras (vision-based approach), the eye-gaze system can be simpler and cheaper, but it needs a good algorithm for detecting the eye-gaze. We may divide the researches in this group into two small groups: detection and tracking systems. In the detection group [6], the user's head must be still while the system trying to detect the eye gaze. On the other hands, the eye-gaze tracking systems [7] can follow the movements of the user's head and eyes. In such systems, another kind of 3D pose of head using stereo camera [8] might be needed for detecting the head position. Clearly, the tracking systems provide convenience for users, but it is still required a good detecting scheme. For example, Kim etc. al. [7] proposed to use longest line scanning (LLS) and occluded circular edge matching algorithm. The method can be applied to a menu of size 8x10 blocks. In this paper, we propose to use the relationship of the displacements from the center of both eyes to determine the horizontal distance and used the eye displacement to obtain the function of both eyes. The remainder is organized as follows. In Section 2, we describe the basic idea of our method. Section 3, is the Least Square straight line. Section 4, is proposal algorithm. Section 5, is the experiment. Section 6, is the conclusion of an experiment.

2. Basic Idea And Proposed Method.

2.1 Basic Idea

The eye-gaze detection based-on a basic configuration of a vision-based approach system shown in Fig. 1, our basic bases on the fact that when scanning horizontally the movements of the left and right eyes are not equal. Hence, there should be a function that maps such displacements to the horizontal distance in the screen.

2.2 Proposed Method

The Figure 1, shown geometry of both-eyes distance related with screen position. Let P_i be the i[tch] point on the screen position, $i = 0, \pm 2, \pm 4, \cdots, \pm n-1$, whose distance from the center is equal to $i * \frac{T}{2n}$, where n is the total number of points in each size and L is the length of the screen. Let r_L be the length of left eye radius from the left side of the image to eye-gaze center, and let r_R be the length of right-eye radius from the eye-gaze center to iris edge.

Let L be the distance of screen. Let h be the distance from the face to screen positions. Let Δx_{Li} and Δx_{Ri} be the displacements from the center of the left and right eyes, respectively. Then, capture the image of the eyes while user focusing at P_i positions, there exists a function f such that $P_i = f(\Delta x_{Li}, \Delta x_{Ri})$.

3. Least Squares of Straight Line Fit.

Straight Line Fit: The problem of eyes movement cause an error for determines the positions while looking at the screen. From basic idea, we obtained the image of the user eyes with P_i points keep in D data set. The data set of eye displacement and positions of screen can be mapping together. The Least Square of Straight Line Fit [9] provides an effective for data set D.

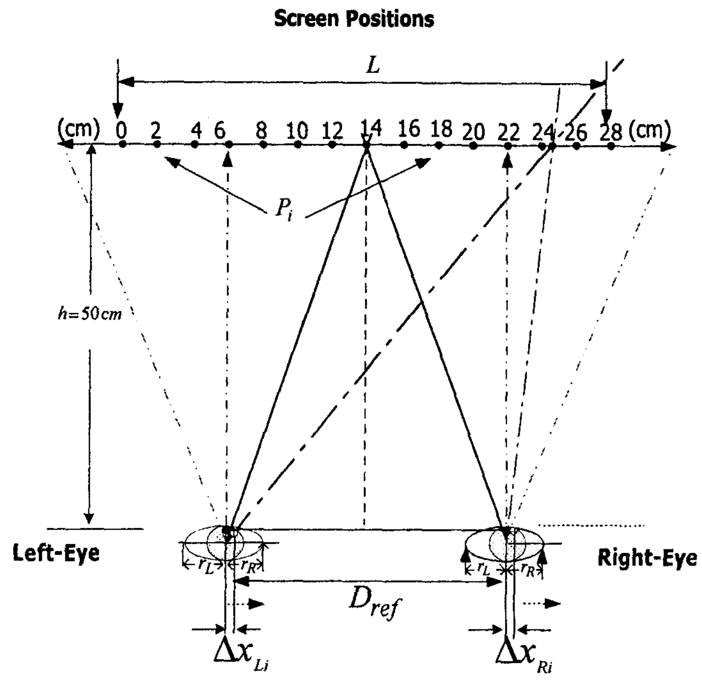

Figure 1. Both-Eyes and Screen Positions Configuration

An Eye-gaze movement while focusing at difference point on the screen could be trend to the curve is a linear polynomial as show in Equation (1).

$$f_{(x)} = a_1 + a_2 x \qquad (1)$$

In Equation (1), could be applied to the function of eye -gaze displacements, which is use to mapping with screen positions as shown in Equation (2).

$$f(\Delta x_{Li}, \Delta x_{Ri}) = a_1 + a_2 \Delta x_k \qquad (2)$$

The error associated with the n points in the data set D of eye-gaze displacement represent in Equation (3).

$$E(a) \stackrel{\Delta}{=} \sum_{k=1}^{n} w_k \left[f(\Delta x_k) - y_k \right]^2 \qquad (3)$$

Here $w_k > 0$ denotes a weight associated with the k th data sample, with the most common case being uniform weighting:

$$w_k = 1, \quad 1 \le k \le n \qquad (4)$$

The polynomial f whose coefficients minimize $E(a)$ is referred to as the weighted least squares fit. Although alternative error criteria can be use, the least-squares objective in Equation (3) is preferred. Indeed, if we differentiate $E(a)$ with respect to the unknown components of the coefficient vector a, this yields

$$\frac{\partial E}{\partial a_1} = 2 \sum_{k=0}^{n} w_k \left[f(\Delta x_k) - y_k \right] \qquad (4)$$

$$\frac{\partial E}{\partial a_2} = 2 \sum_{k=0}^{n} w_k \left[f(\Delta x_k) - y_k \right] x_k \qquad (5)$$

Setting $\partial E / \partial a = 0$ then results in two equations in the unknowns a_1 and a_2. After rearrangement, these equations can be expressed as a linear algebraic system of the form $Ca = b$.

$$\begin{bmatrix} \sum_{k=1}^{n} w_k & \sum_{k=1}^{n} w_k x_k \\ \sum_{k=1}^{n} w_k x_k & \sum_{k}^{n} w_k x_k^{\ 2} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix} = \begin{bmatrix} \sum_{k=1}^{n} w_k y_k \\ \sum_{k=1}^{n} w_k x_k y_k \end{bmatrix} \qquad (6)$$

4. Proposal Algorithm.

The method used to determine the position of the eye-gaze at the screen positions based on vision-based approach by considering the relationship of the both-eye displacement. An accuracy and resolution could be performed by using the result from an experiments and least square algorithm. This section will describe the step of the proposal algorithm.

Step 1: Capture the eyes image.
Step 2: Compute displacement of both-eyes $\Delta X_L, \Delta X_R$.
Step 3: While looking at difference position of P_i point
  Step 3.1: Capture the next image of the eyes.
  Step 3.2: Compute the displacement $\Delta X_{Li}, \Delta X_{Ri}$. and the radius of eye.
Step 4: Compute the ratio of the left/right edge Of both-eyes.
Step 5: Compute the function of both-eyes by Summing the displacement of $\Delta X_{Li}, \Delta X_{Ri}$ to be ΔX_T
Step 6: Testing the function of eye and screen mapping.
Step 7: Evaluation for the accuracy and error of the eye function.

5. Experiment

Condition: These proposed based on head and face of user must be stationary. The distance between the faces of user to screen was 50 centimeters. The resolutions of image are 640×480. The width of screen is 28 centimeters in horizontal plane be divided in to 15 points. The reference on the horizontal plane or the screen positions can be started from the points of 0, 2,4,6,8,10,12,14,16,18,20,22,24, and 28 from the left to right hand side.

5.1 Experiment Method.

These experiment based on image processing by capture an image of user eye by the user focusing at center of the screen in first time. Next, capture the image for the P_i while user looking at difference position on screen. Then, find the both-eyes distance and initial to be the reference position. For the n point of the image, measuring the displacement of the both-eye by measuring from the left-edge of the eyes to the eye-gaze center and from the center of eye-gaze to right-edge referred to step (1-3). The results of eye-gaze image measurement as shown in table 1.

From the Table 1 we obtained the eyes displacement. Then, calculating the ratio of the left per right edge of both-eyes in step 4. The displacement of the eyes denotes by ΔX_{Ri} and ΔX_{Li} referred to the ratio of left and right eyes. In order to mapping the eye-gaze displacement, mush be used the displacement ratio of ΔX_{Ri} and ΔX_{Li} summing together. Then, the function of the both-eye displacement can be represent in Equation (7) is the function of user eye-gaze mapping to screen. Last time, evaluation the function of eye-gaze and used this function to find the position of screen from next experiment.

$$f(\Delta x_T) = f(\Delta x_{Ri} + \Delta x_{Li}) \quad (7)$$

Table 1. Experiment Results.

Pi. Ref (cm)	Right-Eye Left-edge Pixel	Right-Eye Right-edge Pixel	ΔX_{Ri} r_L / r_R	Left-Eye Left-edge Pixel	Left-Eye Right-edge Pixel	ΔX_{Li} r_L / r_R	ΔX_T
0	47.4	17.52	2.70548	47.4	31.95	1.4837	4.18914
2	44.31	19.58	2.26291	45.34	32.21	1.4077	3.67063
4	43.29	21.64	1.99995	43.3	33.36	1.2979	3.29782
6	42.25	22.69	1.86223	41.22	34.03	1.2116	3.07381
8	31.95	23.7	1.34779	35.06	35.04	1.0004	2.34822
10	30.91	25.77	1.19969	32.98	42.25	0.7806	1.98026
12	28.85	30.93	0.93275	31.95	42.25	0.7562	1.68892
14	24.73	27.85	0.88813	30.92	42.31	0.7308	1.61897
16	23.78	29.84	0.79692	29.84	43.22	0.6904	1.48736
18	22.63	36.07	0.62737	28.85	50.45	0.5719	1.19923
20	21.51	39.16	0.54932	27.83	53.59	0.5192	1.06855
22	20.61	41.22	0.49998	26.8	55.65	0.4815	0.98145
24	16.44	42.25	0.38908	24.75	56.68	0.4367	0.82574
26	15.49	44.32	0.34954	21.64	58.74	0.3684	0.71797
28	14.28	45.35	0.31491	19.58	60.81	0.322	0.63694

5.2 The Function of Eyes Mapping To Screen.

The function of the eye-gaze detection for determines the positions where the user focusing on the screen can be achieved by Equation (2-7). Then, considering the Equation (7), this equation referred to the total of the ratio of left-right eye according to changed while looking at difference positions on screen. Thus, data set of the eye displacement D are compose of eye displacement ΔX_T and screen positions denote by y_k. The set of data from experiment consist of ΔX_T and y_k can be mapping in set D.

$$D = \{(4.18914,0),(3.67063,2),(3.29782,4),(3.07381,6),(2.34822,8),(1.98026,10),(1.68892,12),(1.61897,14)(1.48736,16),(1.19923,18),(1.06855,20),(0.98145,22)(0.82574,24),(0.71797,26),(0.63694,28)\}$$

From the data set of the eye displacement and screen positions using Equation (6), to determine the coefficient matrix C and the right-hand side vector b are

$$C_{11} = \sum_{k=1}^{15} 1 = 15$$
$$C_{12} = \sum_{k=1}^{15} x_k = 28.78511$$
$$C_{22} = \sum_{k=1}^{15} x_k^2 = 73.61411$$
$$b_1 = \sum_{k=1}^{15} y_k = 210$$
$$b2 = \sum_{k=1}^{15} x_k y_k = 265.16247$$

(11)

Thus, the linear algebraic system that must be solved to find the coefficient vector a of eye displacement and screen position is

$$\begin{bmatrix} 15 & 28.78511 \\ 28.78511 & 73.61411 \end{bmatrix} a = \begin{bmatrix} 210 \\ 265.16247 \end{bmatrix}$$

$$a = [28.39588, -7.50016]^T$$

Thus, the linear polynomial that best fits the data in uniform least-squares sense, is

$$f(\Delta x_T) = 28.39588 - 7.50016 \Delta x_T \qquad (12)$$

Equation (12), is the function of eye-gaze detection from the data set D of an experiment use to determine the position of the screen.

5.3 Evaluations The Function of Both-Eyes.

Section 5.1 –5.2 be explained about the experiment method and function of the both-eye calculation. This result can be expressed in the Equation (12). Then, we would like to evaluation the accuracy and the error of this function by choose the results of ΔX_T from table 1, to calculating the position of screen with Equation (12). From the function in Equation (12) the results as shown in table 2.

Table 2. The result of Pi from the function of the Eyes

Reference Of Pi	Δx_T	The Point On Screen (Centimeter)	% Error
0	4.18914	-3.02334	100
2	3.67063	0.86557	56.7215
4	3.29782	3.66170	8.457
6	3.07381	5.16173	13.97117
8	2.34822	10.78385	34.79813
10	1.98026	13.54361	35.4361
12	1.68892	15.72871	31.07
14	1.61897	16.25335	16.095
16	1.48736	17.24044	7.75
18	1.19923	19.40146	7.785
20	1.06855	20.38158	1.9079
22	0.98145	21.03485	4.38705
24	0.82574	22.2027	7.48875
26	0.71797	23.01099	11.496
28	0.63694	23.61873	15.64739
		Mean error	23.53%

The result as shown in table 2 and Figure 2, for the position of this function. The accuracy of this function is 76.47% and 23.53% of error.

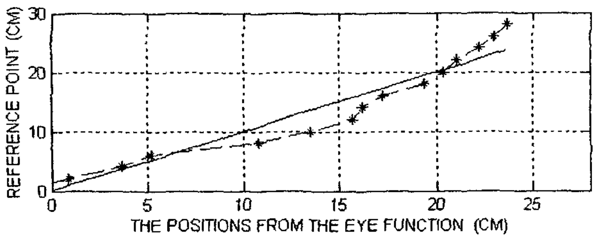

Figure 2. The Result of function of the eyes by least- square

6. Conclusion.

The vision-based eye-gazed detection for these proposed method base on image processing techniques. The experiments are performed to measure the accuracy and resolution in horizontal. The results shown the accuracy of the screen mapping function for the horizontal plane are 76.47 % and the error of this function be 23.53% .The resolution of these method are 15 blocks in horizontal.

7. Discussion

This method provided for only horizontal screen. In future, we plane to proposed for vertical of screen.

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