The Eye Control Password Keyboard Based on Gaze Tracking

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Abstract. Against the exposed problems of traditional enter password method. As well as, it was difficult for people with disability to enter password. Experimental study on the password keyboard based on eye tracking technology. During experiments use a single camera focused on one eye to collecting data. Using the least squares fitting circle and centroid method pinpoint the location of the pupil center and the light spot. Regional mapping based on the geometric relationship between the position vector locating the fixation point. Change eye gaze points to control the password operation. Experimental results show that gaze tracking can be very good application in eye control password keyboard and the application can effectively resolve the dilemma raised.

Introduction

Nowadays password (code) is increasingly important as a tool to protect individual privacy, however with the exposure of various passwords stealing technique and the fact disabled cannot enter password easily, traditional Password (code) input method is no longer sufficient for current market demand. Therefore, a secure and convenient way of password input is required.

Comparing performances of six common eye movement methods concluded in Reference[2] reveals that the Pupil-corneal reflection vector tracking method owns the accurate, little-disturbance technical feature and is suitable for occasions of locating watch point. Moreover, there is an anti-invasion merit coming along with the sight trace technique upon cornea reflect principle[2].

This text is stemmed from above requirements and technical supports, employing pupil-cornea trace technique to test and verify the feasibility of eye control keyboard.

Theory in Eye-controlled password keyboard

By processing and analyzing user`s eye`s picture captured by camera, the positions of pupil`s center and light spot in eyeball membrane coursed by infrared light source can be derived, computing the connection between positional information can consequentially determine the current direction of sight.

If the relative location of eye and camera is unchanged, while the eyeball is moving to focus on different position on screen, the light spot is motionless due to eyeball is almost a sphere, on the contrary, the pupil center, which can reflect the movement of sight, is removing from light spot, hence the vector GP between pupil center and light spot show the trace of sight[3].

Ascertaining the watch point through the movement of eyeball, the duration in which the watch point stay within each designed area will decide whether or not carrying on the password valuing procedure. With inputting 6 numbers as period valuing, an eye control keyboard input operation completes. System’ s operation flow chat as shown in Fig.1.

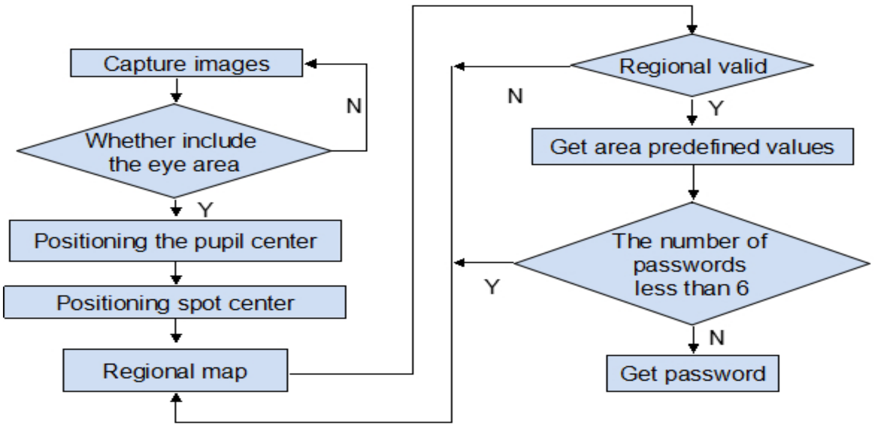

Fig.1: Process of Eye-controlled password keyboard

Image Acquisition

This text choice WinCE platform and DirectShow framework to collect and process real-time images. The traditional image collection under ARM platform mostly adopts V4L technique, utilizing video device provided by Linux to capture image, reference [4][5] is an example of pupil locating though V4L port under IEEE Linux circumstance. The Hough technique used by traditional pupil locating method is inadequate in real-time video environment. Therefore[6], under WinCE+DirectShow environment this text improved the efficiency of pupil locating, consequently realizing 15fps accurate real-time pupil locating.

The framework used in this text as shown in Fig.2.

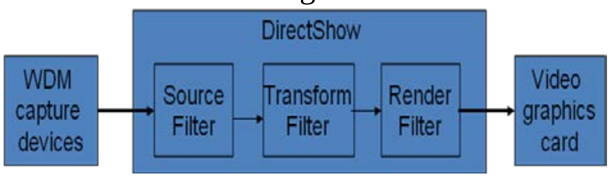

Fig.2: Simple map of DirectShow architecture

Image preprocessing

Image denoising. As for the collected eyeball image, Median filter which can remove noise while keep the image`s margin is used[7]. This is to say, for each dealing Pixel, picking neighbor windows centered it in 3*3, then ascending ranking the 9 density values of picked windows to find out the median as the density of desired Pixel.

Binarizing the image area. The Pixel density Histogram chart of grey-scale map after denoising process, for extracting the pupil, introducing the self-adaption threshold value ensuring approach OTSU to calculate the threshold value in binaryzation upon which the image in binaryzation is worked out[8]. The result of denoising and binaryzation as shown in Fig.3,4.

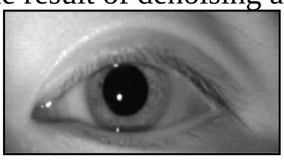
Fig.3: Result of denoising

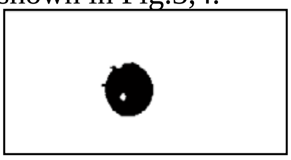
Fig.4: Result of binaryzation

Horizontal and vertical projection. With regard to image in binaryzation, the projection method is involved to build both projections vertically and horizontally to bring out the area where the pupil is and the paralleled X,Y coordinate of pupil center.

Defining the image as I(x,y) and the processed rectangular region as (x1,y1) × (x2,y2), accordingly, the vertical projection V(x) and horizontal projection H(y) are defined as follow:

$$H(y)=\sum_{x=x1}^{x2} I(x,y)\,;\; V(x)=\sum_{y=y1}^{y2} I(x,y) \qquad (1)$$

With the projection stemmed from the above formulas, the region where the pupil settles is clear. The vertical and horizontal projection in experiment as shown in Fig 5,6.

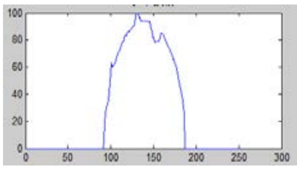

Fig.5: Horizontal projection

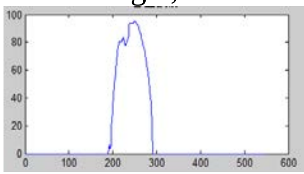

Fig.6: Vertical projection

The grey-scale value of pupil part in eye area is relatively concentrated, hence through setting the lower threshold value for the grey-scale value of pupil to projecting, the crest zone in projection curve is pupil area. After the projection curve zone for pupil area is set, according to projection drawing, the coordinate for pupil in coordinate system for image is around X=250、Y=150, in addition, the average value of the sum of the initiatory coordinates is the approximate radius R to pupil.

Pupil position

Searching for the area of marginal point to pupil upon the center value derived from coarse positioning and radius R. Seeking marginal point in all directions within the mentioned area, whether the absolute difference between the discovered Pixel value and the threshold value for pupil is less than 1 decides whether it is the marginal point for pupil, recording its coordinate if it indeed is. The result of marginal point extracting for experimental image as shown in Fig.7.

According to the discovered marginal point coordinate, using Least squares fitting circle method for marginal point coordinate, and then pinpointing the position of pupil center. Circle equation is: $x^2 + y^2 + Ax + By + C = 0$ .Circle fit result in the parameter values A,B and C for circle equation, the computational formulas for center coordinate and radius value are:

$x_{pc} = \frac{A}{-2}, \quad y_{pc} = \frac{B}{-2}, \quad R_p = \frac{1}{2}\sqrt{A^2 + B^2 - 4C}$. Precise positioning result is shown in Fig.8.

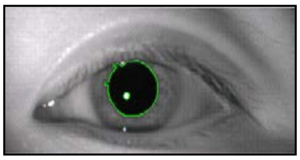

Fig.7: Marginal point of pupil

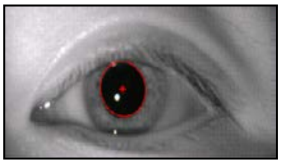

Fig.8: Precise positioning

Spot position

Because the light spot created through eyeball being exposed in infrared possesses traits including small area, high luminance, anti-interference etc, therefore, the circle model centroid with high operation speed is applied to locate the light spot center. In order to improve the accuracy in light spot center locating, different intensity take different Weights in terms of light intensity distribution in light spot area.

Spot Regional center formulas as follows:

$$x_{gc} = \frac{\sum_{n=1}^{N}(x_n \times H_n)}{\sum_{n=1}^{N} H_n}, y_{gc} = \frac{\sum_{n=1}^{N}(y_n \times H_n)}{\sum_{n=1}^{N} H_n} \qquad (2)$$

The implementation of password keyboard

Dynamic partition to password keyboard screen zone by reading a script file. Based on the setting of script file value, reading the stated column number M and row number N. In line with requirements, screen is able to be divided to valuing models such as 3*3(matching value 1-9)、 2*5(matching value 0-9)、4*3(matching value 0-9 and *、#) and so on. The dynamic partition of the value for each pressing zone in flat coordinate system $W_{keyboard}$ as shown in Fig.9.

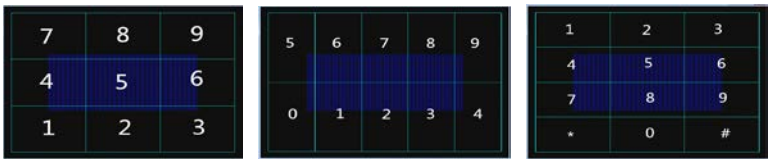

Fig.9: Result of dynamic partitioning

In eye image W_{eye}, from the location diversity between pupil center coordinate P(*) and light spot center coordinate G(•), in other word, the center value of pupil accurate locating (x_{pc}, y_{pc}) and light spot accurate locating (x_{gc}, y_{gc}), the relative location of the above two is secured which is: $x_{eye} = x_{pc} - x_{gc}$, $y_{eye} = y_{pc} - y_{gc}$。

In eye image W_{eye} and keyboard screen $W_{keyboard}$, taking $(X_{keyboard}, Y_{keyboard})$ as the coordinate of watch point on keyboard screen, in the premise that the system do not rotate or rotating angle is tiny, Between the two coordinate systems is an enlarged translation relations, mapping relations for each point within W_{eye} and $W_{keyboard}$ can be expressed as :

$$\begin{cases} X_{keyboard} = k_x * x_{eye} + x_{offset} \\ Y_{keyboard} = k_y * y_{eye} + y_{offset} \end{cases} \tag{3}$$

In the above formula, k_x and k_y are the amplifications of the two coordinate system points in x direction and y direction. x_{offset} and y_{offset} are the offset of the two coordinate system points in x and y direction. Besides, the parameters k_x, k_y, x_{offset}, y_{offset} are chalked up through auto-calibration.

Using 9 point calibration method to demarcate, selecting center point (X_i, Y_i) of each partition region as 9 demarcated watch points. Under the condition of current frequency （15fps）, staring each demarcated points successively for 2s can bring out 30*9 sets of data. As to data of each area, working out center point $(\Delta\overline{x}_i, \Delta\overline{y}_i)$ of matching area through centroid, putting each set of data into equation set of mapping relation of each point on the two flats, an optimal value of parameters k_x, k_y, x_{offset}, y_{offset} in mapping equation set can be deduced by The least squares method.

While password inputting, for avoiding misoperations that will impact the outcome, this text undergo Median filter in course of valuing. Selecting present vector as well as the data of the previous successive 8 frame, deducing mid-value (x_{mid}, y_{mid}) of 8 frame vector in x and y direction respectively, moreover, making this mid-value as outputting point.

Putting the (x_{mid}, y_{mid}) in the duration of valuing for password inputting into equation set (3) brings about the coordinate $(X_{keyboard}, Y_{keyboard})$ of screen area at this moment, through the located range of this coordinate, inferring to the area coordinate (X', Y') at which watch point settle on the keyboard screen, determining key chosen by sight on the basis of the result of the dynamic partition within screen area. Eyeball rolling, sight removing, the selected key changing, eventually, the password inputting accomplishes.

Experimental results and analysis

The eye-control password keyboard test software in this text conduct experiment in nature light, when the partition value of password keyboard screen is 3*3, area setting value, the valuing range of the intra-area coordinate X,Y and coordinate as shown in Table 1.

Table 1: Correspondence between coordinates X、Y range and zone values

Zone No.	Value of zone setting	Coordinates X、Y range of zone divide	Coordinates values (X',Y')
1	1	-300<X<-100, -219<Y<-73	（1,1）
2	2	-100<X<100, -219<Y<-73	（1,2）
3	3	100<X<300, -219<Y<-73	（1,3）
4	4	-300<X<-100, -73<Y<73	（2,1）
5	5	-100<X<100, -73<Y<73	（2,2）
6	6	100<X<300, -73<Y<73	（2,3）
7	7	-300<X<-100, 73<Y<219	（3,1）
8	8	-100<X<100, 73<Y<219	（3,2）
9	9	100<X<300, 73<Y<219	（3,3）

Through Calibrating, this test results in an set of optimal function parameter: k_x =233.8634, x_{offset} =-25.7250, k_y =163.2927, y_{offset} =-14.7617. During the test, the data outcome of the eight successive frame as gazing at number 9 are shown in form 2.

Table 2: Result of eight consecutive frames when gaze at the zone of value setting 9

No.	Pupil center		Light spot center		Vector	
	x_{pc}	y_{pc}	x_{gc}	y_{gc}	$\Delta x'$	$\Delta y'$
1	261.9817	244.9872	261.0000	244.0000	0.9817	0.9872
2	256.8793	250.9242	256.0000	250.0000	0.8793	0.9242
3	256.9652	248.9845	256.0000	248.0000	0.9652	0.9845
4	256.9286	246.9807	256.0000	246.0000	0.9286	0.9807
5	257.9438	243.9615	257.0000	243.0000	0.9438	0.9615
6	254.8493	243.9640	254.0000	243.0000	0.8493	0.9640
7	245.9272	254.8603	245.0000	254.0000	0.9272	0.8603
8	248,9538	258.9119	248.0000	258.0000	0.9538	0.9119

According to the outcome of Table 2, the median (x_{mid}, y_{mid}) to the data of these 8 frames is known as (0.9286,0.9615), plugging that median as input value (x_{eye}, y_{eye}) into the optimal value formulas for the mapping relations on the two flats $X_{keyboard}$ =233.8634* x_{eye} -25.7250, $Y_{keyboard}$ =163.2927* y_{eye} -14.7617, the point coordinate $(X_{keyboard}, Y_{keyboard})$ of password keyboard for this mapping is gained as (191.4406,142.2442). With the paralleled relation between coordinate range of screen partition and area coordinate, the screen coordinate (3,3) at this point is revealed and the right watch value 9 is secured.

Upon screen dividing setting, a set of test outcome data to successively staring at each number is displayed in Table 3.

Table 3: The result when the screen is divided into 3*3

No	G. Z	Pupil center	Light spot center	vector	S.C.After mapping	C.V.	P. W
1	1	(279.2577, 235.3822)	(281.0000, 236.0000)	(-0.9818, -0.7105)	(-255.3264, -1307758)	(1,1)	1
2	2	(282.4382, 238.4184)	(283.0000, 239.0000)	(-0.3127, -0.8990)	(-98.8453, -161.5591)	(1,2)	2
3	3	(288.6178, 239.9988)	(288.0000, 240.0000)	(0.7291, -0.4357)	(144.7808, -85.9093)	(1,3)	3
4	4	(298.9423, 240.9017)	(299.0000, 241.0000)	(-0.6142, -0.0278)	(-169.3676, -19.3072)	(2,1)	4
5	5	(311.5587, 241.0110)	(312.0000, 242.0000)	(-0.0979, -0.0487)	(48.6288, -22.7156)	(2,2)	5
6	6	(309.1528, 249.3142)	(309.0000, 249.0000)	(0.8928, 0.2852)	(183.0671, 31.8084)	(2,3)	6
7	7	(308.6047, 248.7828)	(309.0000, 247.0000)	(-0.7694, 1.1816)	(-205.6486, 178.1862)	(3,1)	7
8	8	(307.8913, 248.2581)	(308.0000, 247.0000)	(-0.2827, 1.2100)	(131.3479, 207.8996)	(3,2)	8
9	9	(248.9538 258.9119)	(248.0000 258.0000)	(0.9286, 0.9615)	(191.4406, 142.2442)	(3,3)	9

According to the result in form 3, the eye control password keyboard in this test is able to correctly implement the function of number selecting. In a practical application, with reinforcing in eliminating the effect of environmental disturbance, it has achieved the level of practical use.

Conclusion

This article studies the principle of eye control password keyboard, introducing MATLAB to theory verifying, under the OK6410-A developing panel with WinCE system, applying Directshow technique for testing, at last the feasibility of eye control password keyboard is testified.

On the basis of this research, the direction for future study is: improving the accuracy and operability of eye control password keyboard through maturing and perfecting the algorithm routine, as well as considering expansibility researches and tests upon how to apply eye control password keyboard in practice.

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