Optica Applicata, Vol. XXXIX, No. 1, 2009

Image password lock system by tracing position information of the pupil

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In this paper, a new method for an improved image password lock system by tracing position information of the pupil is described. The present technology relates to an efficient auto-detecting function, and in particular, to an image password lock system, which can provide the benefits of a novel password input mode without any contact. In this system, a PC camera device detects a movable target object to read a dynamic eye image data. Moreover, the dynamic eye image data has a predetermined shooting range set to be a whole-region image, and the whole-region image has a central region and a plurality of specific password regions. A target eye image is displayed by a display device, and then processed by an image processing device, thereby calculating a center coordinate point of the target eye image in the dynamic image data, compiling a password constituted by a movement position of the target object image, displaying the password, and validating the password. Therefore, the benefits of a novel password input mode without any contact, an efficient anti-theft function, are provided.

Keywords: image password lock system, tracing position information, pupil.

1. Introduction

The application of visual tracking has always drawn attention for its straightforwardness, naturalness and bidirectionalness [1–3]. Obviously, all visible forms of target and command and other input methods are under the guidance of visual input, in which users position the target and other input methods or commands are then introduced [4–6]. The eye-tracking device has become one of the most important human-machine interfaces in which eye movements are related to the information-processing demands of a task. In an eye-tracking system, the user's point of view on the computer screen is estimated, using the vector distance from the center of the pupil in a digitized eye image [7–12]. Eye-tracking devices were initiating in military applications for guiding weapons systems while freeing the pilot's hands for guiding the aircraft through combat aerial maneuvers. Usually these devices include a detection device to detect the bioelectromagnetic signals or image sequences generated by eye movements [13–16].

In this paper, a new method for an improved image password lock system by tracing position information of the pupil is described. For traditional lock forms, most locks are unlocked by manually inputting a password, contacting an identification magnetic card or using a handheld key and the like. To sum up, the locks have the following drawbacks regardless of which forms they take:

1. Unavoidable direct or indirect contact with the locks. Whether the conventional devices are unlocked by inputting password manually, contacting the *handheld* identification with the magnetic card machine or using the *handheld* key, it is inevitable to contact directly or indirectly with the locks by hand, thus increasing the infection risk of the epidemic disease. People who have documents in their hand or are busy working must leave the related documents or their business aside to enter the password to undo the lock, which, in an era where video technology prevails, is rather inconvenient.

2. Inconvenient and invalidation-prone password input mode. If the existing digital password is mostly input by a keyboard, it becomes rather an obstacle for the limb--handicapped. If it is input by voice, it is easily invalidated since it may be overheard by others. These are drawbacks of those commonly used and relatively convenient digital and voice passwords.

Referring to Fig. 1, the system presented in this paper provides an image password lock system by tracing the position information of the eye feature, which mainly includes: a PC camera device (CCD type), an image processing device, and a password validation device. A target eye image is processed by an image processing device, thereby calculating a center coordinate point of the target eye image in the dynamic image data, compiling a password formed by a movement position of the target object image, and then unlocking the system.

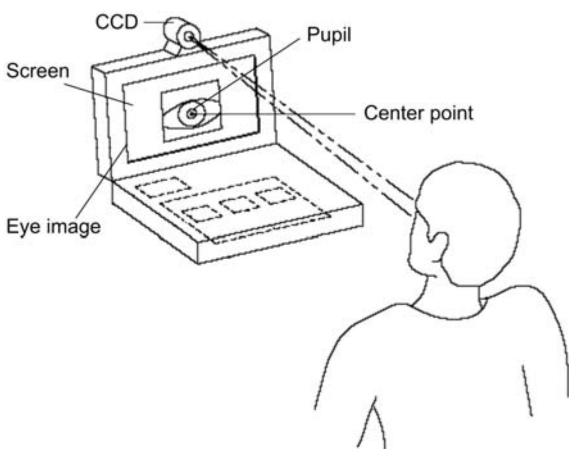

Fig. 1. The architecture of the system.

2. Searching algorithm for the pupil

The system initially assumes the feature object to be a black circle one (organism feature, for example pupil). If it fails to lock the organism feature or the black pixels in the image middle region are too few, the system assumes the feature to be an article feature (for example, the ring, signature pen, or decoration). Then, the central region (100×100 pixels) is set to be a 6×6 mask template and the article feature is defined by the template matching method of shape detection, and thereby the coordinate of the feature is obtained.

As for the aspect of the template matching method of shape detection, the shape and the area of the feature may be varied slightly or the system may mistake other features as the predetermined feature due to varying positions. Therefore, the system will make some structural analysis according to the feature of the structure after the feature retrieving, and then perform the shape detection identification and matching according to the feature of the structure, while the template is regarded as a sub-image having an image structure and used for template matching. In this system, a 2-dimensional matrix with a 6×6 mask size is provided to search for the feature object before the PC camera lens (the object to be detected). Once the feature object is found, it is matched with the feature object (the template) set by the system originally. During matching, the template moves in every region of the object to be detected, and the results of its convolution operation will be examined one by one. When there is a picture of the shape of the object to be detected in a certain region in the picture, the result of the convolution will be of great value, and by setting another tolerable threshold, the system determines the object to be detected as the template of the database, the mathematical expression of which is shown as follows.

Assume the image is $f(x)$, and the template is $g(x)$. First, we assume g is fixed while image f changes as the template moves. That is to say, for the objects of the same shape, the shape and area of their features can be varied slightly due to the interference from the external environment, for example, background colors, light sources or movement positions, and thus the value of $\sum_{[i,j] \in R} fg$ is great. To avoid this case, we employ normalized cross-correlation with

$$C_{fg}[i,j] = \sum_{k=1}^{m} \sum_{l=1}^{n} g[k,l]\, f[i+k, j+1] \tag{1}$$

And the mathematical expression of the template matching method can be modified as follows:

$$M[i,j] = \frac{C_{fg}[i,j]}{\left\{ \sum_{k=1}^{m} \sum_{l=1}^{n} f^2[i+k, j+1] \right\}^{1/2}} \tag{2}$$

As for the value calculated by the above equations, the goodness of fit is higher when greater than a threshold. At first, the user stares at the center zone of the screen. A simple algorithm to get the coordinate of the center point, the position of the center point of the target object image, is calculated as represented by the following formula:

$$(X_f, Y_f) = \left(\frac{1}{K} \sum_{1}^{K} X, \ \frac{1}{K} \sum_{1}^{K} Y \right) \tag{3}$$

in which, K is the total number of the gray values less than the threshold value retrieved after the dynamic binarization of the target object image; X is the x-coordinate of the point of the target object; Y is the y-coordinate of the point of the target object. Similarly, the coordinate of the center point (X_f, Y_f) of the target object image for staring at the center zone of the screen is obtained.

Also, refer to Fig. 2**a** for implementing the system. First, the target object image is assumed to have been selected as the pupil image with a circular shape, and then a very important principle may be applied here. That is, since any perpendicular line (the normal line) at the center point of any tangent to the circle will pass the center of the pupil (the center of the circle), the intersection point of the normal lines of any two tangents must be the center of the circle. Taken from the perpendicular and horizontal lines, the two ends of the black object (organism feature, for example, pupil or hair) are (x_1, y'), (x_2, y'), (x', y_1), (x', y_2), and the center point (X_c, Y_c) of the pupil is acquired based on the following formulas:

$$\begin{aligned} X_c &= \frac{x_1 + x_2}{2} \\ Y_c &= \frac{y_1 + y_2}{2} \end{aligned} \tag{4}$$

Therefore, now we only have to ensure that the two lines x' and y' will intersect with the pupil. Nowadays, the speed of the image input is about 12–30 frames per second. For the size of the images, as long as the center point of the pupil on x' and y' is located at the same position as the previous center point of the pupil (X_c, Y_c), the two lines will be assured to intersect with the pupil, and the error will not accumulate with the elapse of service time.

Second, as shown in Fig. 2**b**, the system incorporates a method of edge searching between three lines, which employs the parallels of each tangent spaced apart from the tangents by a width of 5 pixels, to ensure that the obtained tangents are those on the edge of the circle; and one-dimensional coordinates of these two points are obtained, then we can find the coordinate of the center point of the target object image, and thus the reexamination is complete.

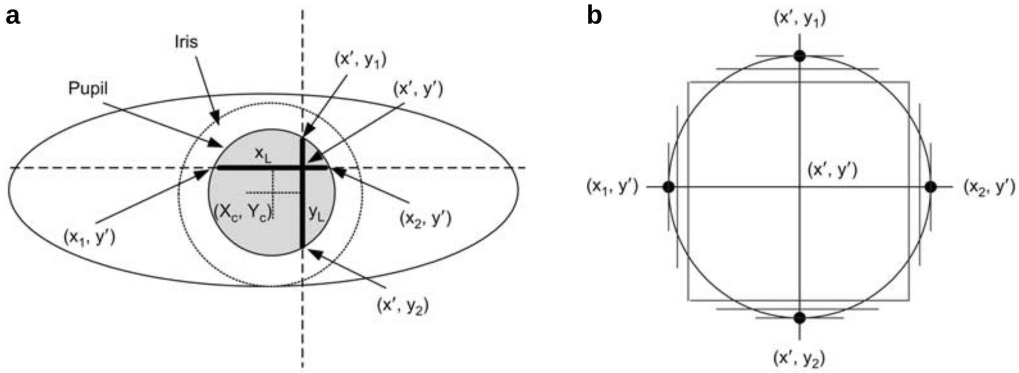

Fig. 2. The calculating process (**a**) to (**b**) for the coordinate of the center point in accordance with the system.

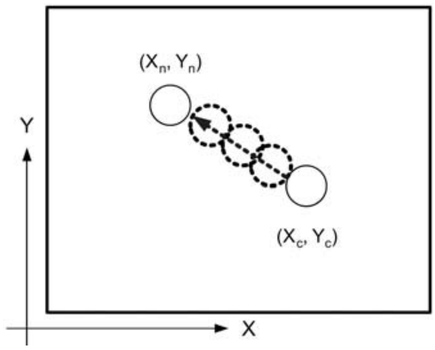

Fig. 3. Calculating the dynamic image search principle.

The coordinate of the center point (x', y') in the figure is gained based on the following formulas:

$$x' = \frac{x_1 + x_2}{2}$$

$$y' = \frac{y_1 + y_2}{2}$$

After finding the center point of the target object image, the system proceeds to the validation process. Then, the user has to move along a specific path according to the coordinates indicated by the system, as shown in Fig. 3, to confirm whether the system has retrieved the feature object. If not, the system must return to the initial setting to retrieve the feature object once again.

In the aspect of searching for the target object (the pupil), first we adjust the proper binarization threshold value T for the image input and at the same time calculate the coordinate of the center of the pupil, then activate the dynamic image search system and set up a dynamic image search frame by taking the center coordinate (X_c, Y_c) as the initial value

$$T = \frac{1}{mn} \sum_{x=1}^{m} \sum_{y=1}^{n} I(x, y) \tag{5}$$

where $I(x, y)$ is the brightness value in different coordinates, m and n are the size of calculating area, T is the threshold value calculated. Assume the X-axis search range of the dynamic image search frame is X_s and the Y-axis search range is Y_s, then the dynamic image search range is calculated to be within the four points $(X_c \pm X_s, Y_c \pm Y_s)$ by taking the coordinate of the pupil center as the center. When the pupil moves, calculate the next coordinate of the center point (X_n, Y_n), and set up a new dynamic image search frame by taking (X_n, Y_n) as the center, and then continue to search for and calculate the coordinate of the next center. The process cycles until the target to be searched in the dynamic search frame disappears beyond the search range of the dynamic search frame (here the center is set to be zero, that is, $X_n = 0$ and $Y_n = 0$), then the system searches for the target again, calculates the center coordinate of the target and then starts to set up another dynamic image search frame and continues to search for the next target center, and the process recycles so forth. Thus, the search range of the whole search frame (R_{sX}, R_{sY}) can be represented by the following formulas:

$$R_{sX} \in \begin{cases} (X_0, X_i) & \text{if} \quad X_n = 0 \\ (X_c - X_s,\ X_c + X_s) & \text{if} \quad X_n \neq 0 \end{cases}$$
$$R_{sY} \in \begin{cases} (Y_0, Y_i) & \text{if} \quad Y_n = 0 \\ (Y_c - Y_s,\ Y_c + Y_s) & \text{if} \quad Y_n \neq 0 \end{cases} \tag{6}$$

in which X_0, Y_0, X_i, and Y_i represent the X-coordinate and Y-coordinate of the starting point and ending point of the initial search range, respectively. By calculating with the dynamic image search principle, the system can maintain better stability. When the user moves along a specific path, if the movement coordinate point of the user has not reached the neighborhood of the coordinate point indicated by the system, the system will make a sound to notify the user that the current distance is still away from the requirement and further movement following the coordinate points indicated by the system is needed. The user then has to properly adjust the distance between the user and the PC camera lens. After the movement along a specific path, the system will make a 'beep' sound, which indicates the step is ended.

If the validating process fails, that is, the system fails to trace the organism feature or article feature effectively, the system will return to the initial setting, and the user repeats the step to enter the system again.

After the above validating process, the system proceeds to the encoding process, in which the system will trace the movement positions of the organism feature or the article feature (that is, the target object image) to encode, and divide the movable region into eight positions. For a 360° space, the region can be divided into 8 equal parts, and the angle of each position is 0°, 45°, 90°, 135°, 180°, 225°, 270° and 315°, with the angles corresponding to the numbers 1 to 8 as shown in Fig. 4. The collection of these numbers forms the user's password. The system must first set up a password database for the user, with the length of the password being predetermined to be 4 to 8 digits.

At first the user gazes at the center point of the screen, so we can obtain the corresponding point (X_f, Y_f) in the eye image. When the user gazes at a specified

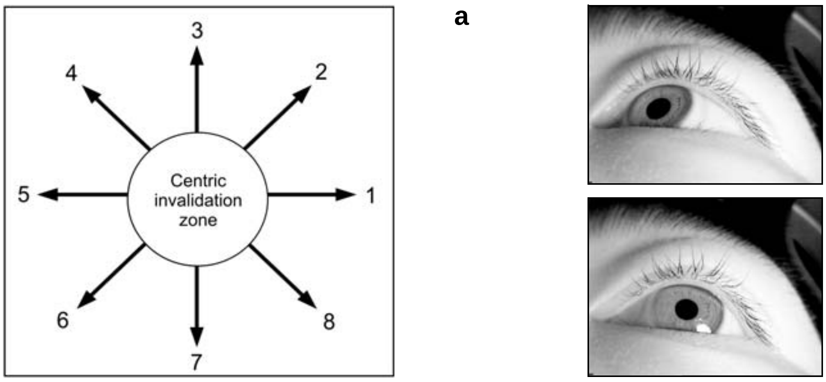

Fig. 4. The movement along the specific path, the codes of the eight regions and centric invalidation zone in accordance with the system (**a**). Positions of the eyeball at up left region (code 4) (**b**). Positions of the eyeball at right region (code 1) (**c**).

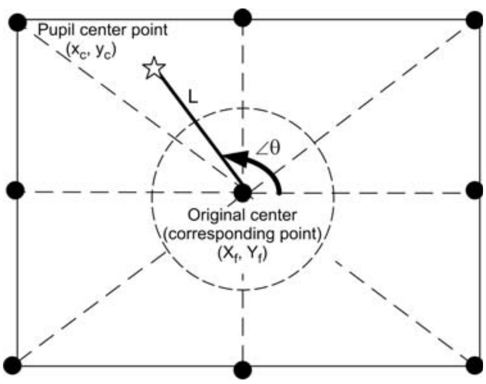

Fig. 5. Polar coordinates mapping relationship between the corresponding point and the pupil center point

region, we obtain the pupil center point (x_c, y_c) in the eye image, then transfer to polar coordinate in $L \angle \theta$ expression (Fig. 5)

$$L = \sqrt{(X_f - x_c)^2 + (Y_f - y_c)^2}$$

When $L < L_z$, the stared point falls in the centric invalidation zone where L_z is the radius of centric invalidation zone.

If the stared point falls in code n region, the relation of code number and value of $\angle \theta$ can be referred to as follows:

$$\begin{aligned}
&\text{if} \quad \frac{\pi}{8} > \theta \quad \text{or} \quad \theta \geq \frac{15\pi}{8} \qquad \text{code number} = 1 \\
&\text{if} \quad (n-1)\frac{\pi}{4} + \frac{\pi}{8} > \theta \geq (n-1)\frac{\pi}{4} - \frac{\pi}{8} \qquad \text{code number} = n \quad (n = 2\text{–}8)
\end{aligned} \tag{7}$$

3. Experiment result and discussion

The image password lock system (Fig. 6) comprises: a PC camera device; a validation module of the target object movement, for outputting a password corresponding to one of the specific password regions (when the center point of the target object image moves toward one of the specific password regions from the central region and then back to the central region); a password display module, for displaying the password outputted on the display device; and a password validation device, for comparing whether the password is the same as a predetermined correct password (when the password is the same as the predetermined correct password, it outputs a password--correct action).

The eight specific password regions are: right of, top right of, below of, top left of, left of, bottom left of, bottom of, bottom right of the central region, and represented by 1, 2, 3, 4, 5, 6, 7, and 8, respectively. The validation module of the target object movement outputs a warning action to point out that the specific password region has not been reached when the center point of the target object image moves toward but still away from the specific password region.

The encoding is utilizing the target object image captured, taking the pupil as the target object. According to the initial setting of the system, the feature needs to be at the center point of the PC camera lens initially. For example, the user conduct encoding by moving the feature himself; here we only encode four codes, the order of which is above (3), left (5), below (7), and top right (2), respectively, and the center point positions of their target object image are calculated, then a password ‘1752’ is obtained.

Finally, a password validation device is used to compare whether the password is the same as the correct one predetermined; and if so, it outputs a password-correct action, for example, computer or mobile phone booting, file open, system entry, gate lock unlocking, system entry of the notebook and the like.

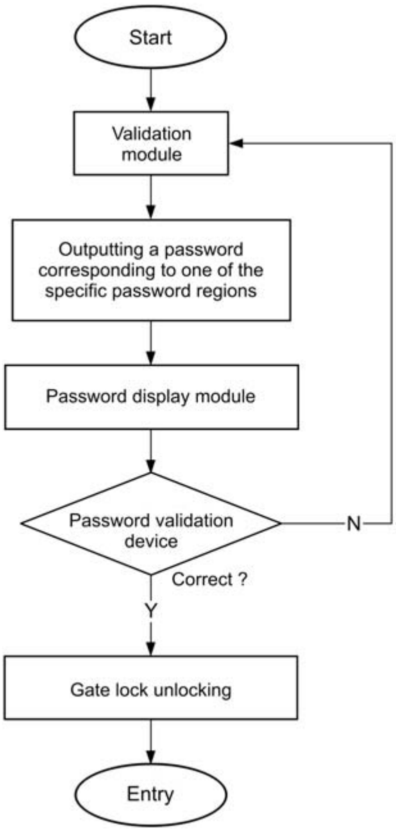

Fig. 6. The block scheme of system components and procedures.

When the PC camera lens of the imaging device is shielded with a hand to start an initial setting of the image password lock system, and the lens has shielded with the hand for a preset time, the image password lock system is in a standby state, and when the hand is away from the PC camera lens with the preset time passed, the PC camera device outputs an indicating signal to inform the user and retrieves a feature of the target object before the PC camera lens, where the target object has a distinct color from a background to avoid failing to calculate the center coordinate point of the target object. The system will make a sound to notify a user that the user moves following a coordinate points indicated by the image password lock system when a movement coordinate point of the user has not reached a neighborhood of the coordinate point. When manipulating the system, the users may decrease the ability of staring because of deficient concentration, exhaustion of the eyes or external factors. Therefore, different users may obtain different testing data. Table 1 shows the important characteristics of the system.

The password of the password database the system has built would be 4 to 6 significant digits. The system was tested for different combination of the digits in 4 digits and 6 digits password. Table 2 shows the statistics of the experimental results of the testing, and we can know the more digits are set, the more time it takes

Table 1. Specifications of image password lock system.

Interface	USB 2.0
Image device	CCD camera with 1/4" chip
Machine vision components	MultiCapture
Image retrieving resolution	640×480
System resolution	1024×768
Frame per second	More than 25 fps

Table 2. The experimental results of the image password lock system.

Item	4 significant digits of password	6 significant digits of password
The average time spent creating the users' passwords	19.3 s	35.1 s
The average time spent activating the system	10.2 s	17.1 s
The failure ratio	1.6%	3%
The ratio of success activating the system two times	98.6%	97.3%

to build a password database and activate the system; and the failure ratio (namely, the probability that the user cannot enter the correct password region) would increase too. However, as the users' skill improves, the failure ratio drops. Usually, if the system could not be activated the first time, it could be activated the second time.

4. Conclusions

In this paper, we present an image password lock system by tracing the position information of the pupil feature, which is provided with a password input mode without any contact. Therefore, the advantages and efficacies of the present system can be summarized as follows.

1. Avoiding any contact. The present system utilizes the movement positions of the pupil, head or article feature as passwords for entering a certain system (computer system) or entrance guard. In this system, the user does not need to make any contact such as inputting a password manually, contacting using an identification magnetic card, or using a handheld key and so on.

2. A novel password input mode. The present system takes the positions of the pupil feature as the basis of password input. Voice is not needed, and the disadvantage of overhearing is avoided; in addition, inputting by keyboard is not needed either, and thus the infection risk of the disease caused by touching an article is eliminated, which is a great help for the limb-handicapped. The password input mode is quite novel.

3. Effective anti-theft function. The present system traces the positions of the specific organism or article feature as the input basis for password lock. In other words,

the form of lock is no longer the combination of limited numbers and characters. With such a design, the previous technique of decoding a password by guessing the characters or numbers depending on the information related to the person who sets the password is no longer effective. Because the specific organism or article forming the password varies, it is rather impossible to decode the password by computing a plurality of combinations of the characters and numbers with a computer. Therefore, with such a set of password locks, an effective anti-theft function is achieved.

Acknowledgements – This work was sponsored by the National Science Council, Taiwan, Republic of China under grant number NSC 96-2221-E-035-099-MY3 and the Chung-Shan Institute of Science and Technology under grant number BV91U14P.

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Received April 19, 2008
in revised form June 14, 2008