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Study of Eye Blinking to Improve Face Recognition for Screen Unlock on Mobile Devices

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Abstract – In recently, eye blink recognition, and face recognition are very popular and promising techniques. In some cases, people can use the photos and face masks to hack mobile security systems, so we propose an eye blinking detection, which finds eyes through the proportion of human face. The proposed method detects the movements of eyeball and the number of eye blinking to improve face recognition for screen unlock on the mobile devices. Experimental results show that our method is efficient and robust for the screen unlock on the mobile devices.

Keywords: **:** Eye blinking, Mobile device, Face recognition

1. Introduction

As new applied services related to smart mobile devices associated with social network are emerging constantly, in order to prevent non-owner from being able to operate directly the built-in system of mobile device, screen unlock function is gradually applied. However, due to today's social network popularity, some interested people might be able to steal personal data from the network, and this function became easier to be broken. Therefore, in this study, "eye blink" function is associated into the system to make sure that the user in front of the mobile device is the right person instead of a photo so as to protect personal data within the mobile device and to reduce cheating issue from human face.

According to the statistics of Seongwon Han [1], in the research of human computer interaction, the use of camera to conduct human eye tracking and eye blink were widely used with a main goal to help disabled person or a person with limited exercise function and to provide an effective computer aided system to such person. In order to increase the popularity and convenience of this technique, many scholars are involved into the related research fields.

Face Recognition is, in smart mobile device, one of the technologies used to conduct identity authentication. The acquisition of "face features" of face image is used as an unique identification information, and Pattern Recognition technique is used to conduct processing and computing technique on the biological feature information of face image [2]. For such authentication way, the photos of users' head can be used to break such authentication system, meanwhile, due to the popularity of today's social network, interested people might use network to get user's photo. Therefore, in this study, in order to improve such drawback, an eye blink technique is associated into the system so that the risk of exposure of personal information is reduced. The main objective of this research is to improve the method proposed in the thesis in 2014 by Shih-Ming Peng [2], meanwhile, the same environment and image database were adopted to conduct the test and to evaluate the performance.

Since the Face Recognition technique used in this paper can be broken through the use of photo, for this drawback, this paper has added the eye blink, through the function of camera in front of the mobile device. Huang et al. [22] proposed a space search optimized polynomial neural network classifier (PNNC) based on a data preprocessing technique and simultaneous tuning strategy to balance optimization strategy in the space searching PNNC. On the other hand, Huang et al. [23] presented a concept of fuzzy wavelet polynomial neural networks (FWPNNs) with the concepts and the constructs of polynomial neural networks and fuzzy wavelet neurons (FWNs). Since they both can train the neural networks to recognize the eye region based on the face image database, they could improve the performance for the proposed eye blink detection. Therefore, our future work can extend to study on PNNC and FWPNNs for the eye blink detection with considering trade-off between the efficiency and the effectiveness on the mobile devices.

The proposed method is major used to user authentication in mobile security. More and more consumers prefer mobile payment for shopping to traditional payment in their daily life. Several non-biometric authentications such as NFC (Near Field Communication) and RFID (Radio Frequency Identification) always lead to data leakage or authentication errors. Since existing biometric authentications such as fingerprint, face recognition, and iris recognition perform not very well and suffer from secure issues on the mobile devices, it is indispensable for

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mobile privacy to improve the conventional biometric authentication with the proposed eye-blink detection. Our method has low computational complexity and high accuracy such that it is efficient and effective to run not only on the mobile device but also on other platforms with necessary user authentication. Our method is not limited to mobile devices, while it can be widely applied to financial transactions, border and airport controls, home or building security, access control, and so on.

2. Related Works

2.1 Eye detection

Eye detection technologies were widely applied in many kinds of fields, especially in the technologies published by Michael Jones et al. [3], which had used the comparison of eye features with feature database and resulted in a giant progress in the eye detection related techniques. However, this method had lots of drawbacks. When there was interference from environment and when eye resolution was worse, correct detection of eye will be a failure. If the eye information in the detected image was not featured values within the database, it will affect the detection accuracy. Lots of researchers had improved on such technique or tried to find out alternative methods. Torricelli et al. [4] had proposed four image processes to replace the use of features value comparison eye detection method, and these four processing methods were eye blink detection, area sorting, the selection of the area within a frame, and the recognition of eye area.

2.2 Static and dynamic

In static and dynamic environment, methods used in eye tracking will have different tracking methods due to different limiting conditions. According to proposition made by Han [1], under static environment, it was needed to suppose that the user's camera was fixed. There was rare chance for user to come out of the camera scope, under such condition, and the eye tracking can be mainly divided into two stages, namely: detection stage and tracking stage.

2.3 Haar feature-based cascade classifier

Haar Feature-based Cascade Classifier was proposed by Paul Viola [5] and was enhanced by Rainer Lienhar [6]. Classifier is called cascade, and the classifier contains several simpler classifiers, which are called level. When candidate object passed threshold value limited by each layer, it was then identified as target object. When the candidate passed the layer, such action was called boosting because in each level, basic classifier designed by different weighted voting was used to conduct the scoring.

2.4 Eye blinking state recognition

Human eyes will complete eye blink action unconsciously or autonomously within a second. The eye tracking can avoid the severe movement of the face. It can locate the eye parts of the face, and then through binarization, the search range is reduced to a pupil location. Through the consequent image subtraction method, the pixel values of objects in the next time point are overlapped and subtracted mutually.

Lee et al. [7] had used an eye state recognition method to conduct consequent images so as to detect the black pixel change of the eye to judge eye opening and eye closing. First, the image of the neighborhood of eyes was acquired, and the image was converted into binarization. Next, two methods and threshold values proposed by Lee et al were used to find out eye closing states. One of the methods was the recognition of short eye closing state with the implementation of black pixel subtraction in the consequent images. The value accumulation method was implemented to judge whether the threshold value was achieved or not. Another method was the recognition of long time eye closing state, through the use of black pixel value of consequent eye closing, and multi-value accumulation processing was implemented to pass the threshold value.

2.5 Application of eye blink

Drowsiness and the point of attention monitoring system were proposed by Batist [8], which was the earliest system that was applied in an eye blink technique. Through the installation of a camera in the car or in the cockpit of an airplane, the detection of head rotation and eye blink frequency of the user were used as important clue target to detect whether the pilot can meet the leveling set up by the system. This was a feasibility application evaluation test to ensure that the pilot can remain alert continuously.

The paralyzed blink detection was proposed by Udayashankar and Atish et al. [9], which was an eye blink supporting system designed for assisting motor neuron diseases). Through the use of a webcam accompanied with their designed App, the detection of eye blink frequency was used as important clue target. According to the detection time of 10 seconds, the eye blink frequency of the user was observed to be used to control the home electric appliance. For example, three times of eye blink can be used to turn off the lamp, and five times of eye blink can be used to turn on the voice recorded in advance by the computer. The care provider does not have to stay beside the patient of motor neuron diseases all day long, and the patient can handle a few things by himself.

Eye phone was proposed by Miluzzo et al. [10] and it used the App on smart mobile devices to start front-facing camera to track the user's eye and to detect eye blink. In such App, it will follow the eye blink count and eye movement of the user to simulate the mouse clicking so as to operate other Apps.

3. Proposed Method

3.1 System Architecture

In this section, an eye blink technique in association with face recognition is proposed to improve the application of cheating of screen unlocking by a human face. When the user operates the mobile device, it needs to use face recognition authentication to complete user's identity identification before the user can enter the mobile device system. The system architecture can be divided into five blocks, which are respectively face detection, face recognition, face database, eye detection, eye blink detection. The function of each function is described as follows:

A. Face acquirement: The front-facing camera of the mobile device acquires a face image.
B. Face recognition: The face recognition can find a face from the face image with matching face samples on a face image database.
C. Face database: It stores the acquired face images and other public face images to be used as face samples for search.
D. Eye detection: It locates the eye regions of the face image.
E. Eye blink detection: It recognizes the eye-blinking features and counts the number of eye blinks.

When the system starts, it will acquire one image each second. Next, it will find a face from the face image with face samples on a face database to achieve user's identification. If she/he is identified, the eye detection will start. Finally, the eye blink detection counts the number of the eye blinks within two times, the screen will be unlocked.

3.2 Face detection

Face feature database provided by Android OpenCV is adopted, and it can be divided into a face detection function and a face recognition function. For the face detection function, through Haar feature, face features will be automatically detected to find a face so as to enhance automatic control on face recognition authentication to reduce the execution time. Eigenface and Fisherface are adopted to set up face image model, and Kth-Nearest Neighbor (KNN) is used to compare the featured points. Therefore, for the face recognition authentication mechanism, two feature acquisition methods of Eigenface and Fisherface will be used respectively for the development. The final part is to distinguish the difference between the images of different people, and histogram equalization is used to remove external environment light source and to enhance face feature comparison.

3.3 Eye detection

Eye detection: The conventional eye blink detection cannot achieve high precision as a user wears glasses with a thick frame and color lens. In addition, the specular reflection of the lens also degrades the performance of the traditional eye blink detection. This is because parts of eye regions are occluded by the specular reflection of the lens and are distorted by the thick frame in the image. Therefore, we propose a method to efficiently and effectively detect eye blink with or without the glasses or even with color lens. Our method is robust against the reflection of the lens and the thick glasses frame to detect eye blink since the proposed method can precisely locate the regions of eyes by using an adaptive geometric ratio of a human face with or without wearing glasses. Specifically, our proposed eye blink detection can be adaptive to eye shape, scale, skin color, and the size of the human face with or without wearing glasses in the image. In addition, since the patterns on the binary eye image caused by the specular reflection of the lens are different from that of the eyes without wearing glasses, our method can further adjust the detected eye regions by detecting the spots of the reflection. Fig. 1 shows a flow chart of our proposed method.

In the experiment, binarization image of the user not wearing glasses is detected, and the threshold value of

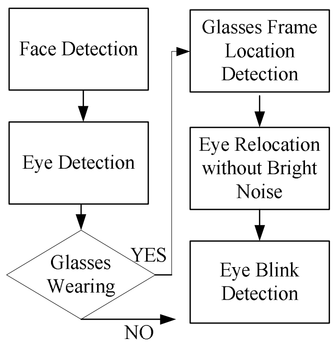


Fig. 1 Flow chart of our proposed method

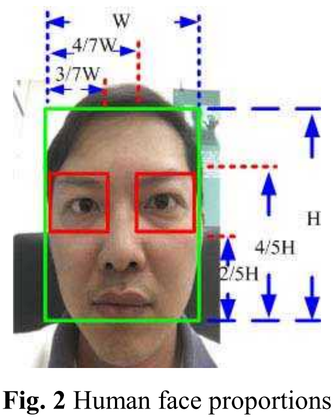


Fig. 2 Human face proportions

black pixel of face is 30%, in order to let user wearing glasses be able to use this program, black pixel allowance is enhanced by 5% to increase recognition range, and the program will see the glasses as part of the face so that it won't be affected by the glasses frame. Next, new eye detection model is added to capture continuously eye information so that the system can own face detection and eye detection models to facilitate later eye blink.

After the face detection, our method locates the position of eyes on the face image. Our method is based on the geometry of the human face [12]. We devise a geometric ratio based on the arrangement of facial features. Specifically, given the height H and the width W of the face image, eyes are vertically placed between 2/5H to 4/5H from the bottom of the chin as shown in Fig. 2. The right eye is located between 0 to 3/7W, and the left eye is placed between 4/7W to W from the left boundary of the human face as depicted in Fig. 2.

After detecting the location of the eyes, our method determines whether the user wears glasses or not. We observe that the number of edges on the detected eye regions under the glasses-wearing image is different from that of the no-glasses image. Therefore, we use the horizontal projection on the detected eye regions to determine the glasses wearing. Our method adopts the horizontal projection to scan the horizontal edges of the binary image along the detected eye regions as shown in Fig. 3(a). We also use the horizontal projection to scan the horizontal histogram of the binary no-glasses image along the center of detected eye regions as shown in Fig. 3(c). Figs. 3(b) and 3(d) demonstrate that the horizontal projection of the glasses-wearing image has more peak values than that of the no-glasses image. If the peak values of the horizontal projection on the detected eye region are greater than or equal to 3, this image presents a glasses-wearing face. This is because the upper and lower boundaries of the glasses frame and the eye-lip features yield large horizontal edge information.

After glasses-wearing detection, we adjust the detected eye regions of the face image to further locate eye regions within the glasses frame. Specifically, our method adopts the horizontal and vertical projections on the detected eye regions to determine new eye regions within the glasses frame. The peak values of the horizontal projection on the detected eye region indicate that the upper and lower boundaries of the glasses frame. On the other hand, the peak values of the vertical projection on the detected eye region point out that the left and right boundaries of the glasses frame. Figs. 4(a) and (b) demonstrate the horizontal and vertical projections of the detected right eye region respectively. Similarly, Figs. 4(c) and (d) shows the horizontal and vertical projections of the detected left eye region respectively.

When parts of the detected eye regions are occluded by the specular reflection of the lens in the image. Since the patterns on the binary eye image caused by the specular reflection of the lens are different from that of the eyes, our method can further adjust the detected eye regions by detecting the spots of the reflection. Fig. 5(a) shows that the reflecting points on the lens are bright and thereby lead to large gray-level values. Therefore, we can easily locate these reflecting points by using a threshold T to binarize the face image. Fig. 5(a) depicts the regions of the

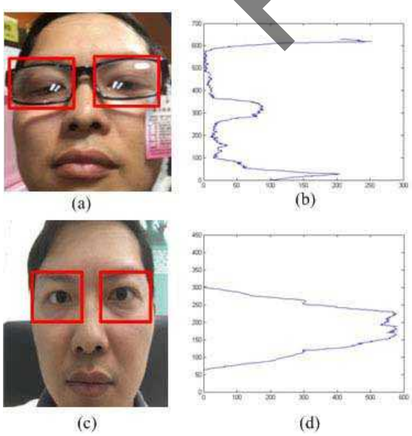


Fig. 3 Glasses-wearing detection: (a) eye detection with glasses wearing, (b) horizontal projection over the red eye region of (a), (c) eye detection without glasses wearing, (d) horizontal projection over the red eye region of (c)

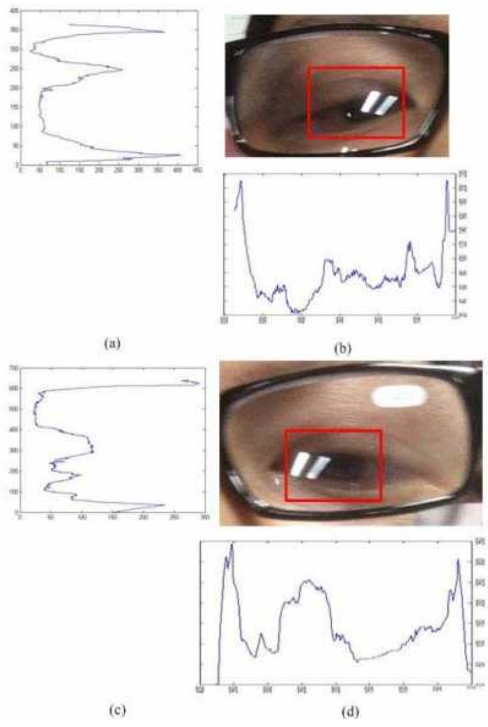
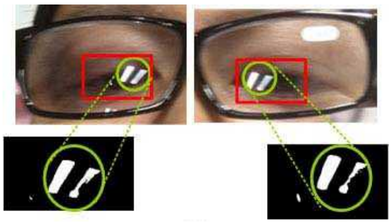
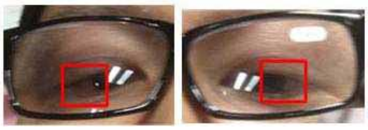


Fig. 4 Eye relocation under glasses wearing: (a) the horizontal projection of a right eye, (b) the horizontal projection of a right eye, (c) the horizontal projection of a left eye, (b) the horizontal projection of a left eye



(a)



(b)

Fig. 5 Reflection detection: (a) bright point detection; (b) refined eye regions

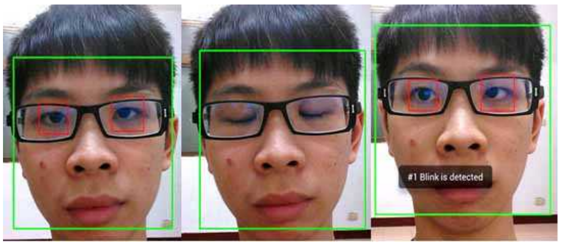


Fig. 6 Eye blinking detection result

reflecting points and several bright noises. After detecting the location of the reflecting points, we further adjust the detected eye regions to insure that the reflecting points are not inside the regions. Fig. 5(b) illustrates the refined eye regions without the reflecting points.

3.4 Eye blink detection

After acquiring eye templates, we focus on the refined eye location, and then use equation (1) to determine whether the refined eye image is of an unchanged state [12]. In Eq. (1), R is a correlation coefficient, T is a template image, and X and Y are original image pixel coordinates. Correlation coefficient is a measurement of the similarity between the present left eye image and the preserved template with eye opened. The correlated changes of calculated short time eye blink (lower than 200 milliseconds) or long time eye blink (more than 200 milliseconds) are conducted through the change of correlated coefficient of time. The time of autonomous eye blinks is over 250 milliseconds. Therefore, this is a threshold to determine whether there is eye-blink or not. Fig. 6 demonstrates the results of the eye blink detection.

$$R(x',y') = \frac{\sum_{x',y'} T(x',y')\ I(x+x',y+y')}{\sqrt{\sum_{x',y'} T(x',y')^2 I(x+x',y+y')^2}} \qquad (1)$$

4. Experimental Results

4.1 Experimental setup

The experimental environment of this study uses Windows 7 as an operating system with the installation of Eclipse JAVA compiling software. Android system development kits such as Google Android 4.2 SDK, OpenCV Android SDK 2.4.10 and JavaCV SDK 0.5 are adopted to develop an eye blink technique.

Before the experiment, the precision of the eye blink is evaluated in advance. For the eye blink detection, the evaluation is defined by Królak [12], and the effectiveness of the proposed method is verified through precision and recall curve, and the accuracy. The eye blink detection is assessed on both glasses wearing and no glasses wearing.

According to the experimental environment, the Apps of eye blink unlocking and face recognition unlocking are be compared each other through the front-facing camera of mobile device. The brightness of the experimental environment is remained to be the same as that of the regular indoor environment, that is, 100 to 1000 lumens as shown in Fig. 7.

There are 100 participants including 67 males and 33 females in the experiments. Among them, there are 62 participants wearing glasses including 34 participants wearing glasses with thick frame and 28 participants wearing glasses with thin rim. For face recognition, each participant takes 40 photos under different light sources, and there are totally 4000 face images in the face image database. In order to evaluate the unlock rate and failure rate curve of the proposed method as compared to the traditional face recognition, we also make participants' face masks.

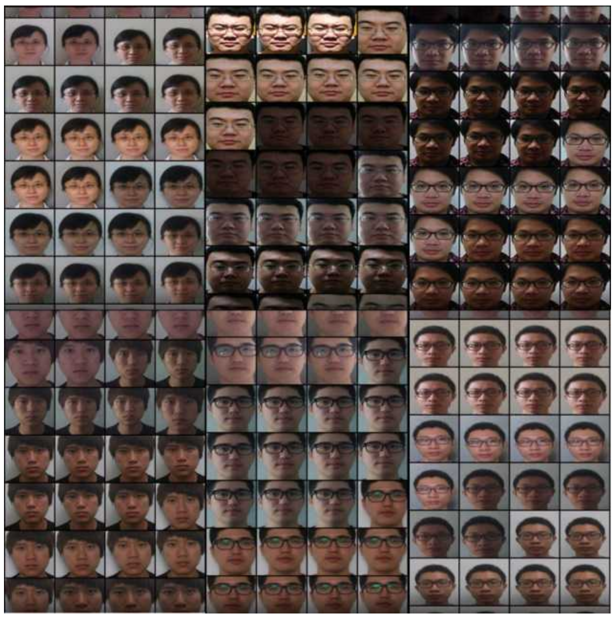


Fig. 7 Parts of face image datasets

Each eye blink detection algorithm is evaluated by using huge public image datasets from the Closed Eyes in Wild (CEW) [11] and ZJU [21] databases. Specifically, in the CEW dataset, it contains 2423 subjects, among which 1192 subjects with both eyes closed are collected directly from Internet, and 1231 subjects with eyes open are selected from the Labeled Face in the Wild (LFW) database. On the other hand, in the ZJU dataset, it contains 80 eye blink video clips, and there are 4 clips per subject: a clip for frontal view without glasses, a clip with frontal view and wearing thin rim glasses, a clip for frontal view and frame glasses, and a clip with upward view without glasses.

We select major related works Krolak [12] and REGT [4] to be compared with our proposed method. Specifically, Krolak et al. proposed a vision-based human-computer interface to detect voluntary eye blinks as control commands by using Haar-like features for the face detection, and template matching based eye detection and eye-blink detection. In REGT, Torricelli et al. presented the eye blink detection by using a view-based remote eye gaze tracker (REGT) component based on frame differencing and eyes anthropometric properties.

4.2 Performance analysis

The average execution time of the face recognition authentication under our method is 4.92 seconds, and the average execution time of the eye blink authentication under our method is 14.92 seconds.

In this section, "user self", "color photo" and "face mask" are evaluated. During the experiment of user identity authentication in person self, each participant personally uses each user identity authentication on the mobile devices. However, each algorithm may be failed when the faces have different angles, and out of detection distance, and rich expression. These cases degrade the accuracy of each algorithm. Fig. 8 shows that our method is slightly superior to the face recognition under the user-self identification.

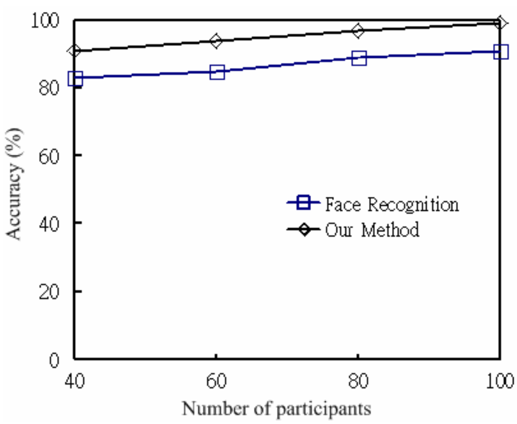


Fig. 8 Accuracy of face recognition and eye-blink detection under the user self

In the "color photo" recognition, we print the color photos of the user in an A4 size. Fig. 9 shows that the color photos of the user can easily cheat the face recognition. The eye blink detection can perform better than the face recognition in the color photos of the user. However, the color photos of the user under the hand shake deteriorate the performance of our method due to the false alerts of the eye blinking.

In the face mask, we make the masks of the users from the color photos of the users. Fig. 10 shows that the face recognition is still cheated by using the mask of user's color photo. Fig. 10 also demonstrates that our method can easily recognize the fake user identity of the mask since our method uses the horizontal and vertical projections of the eye region to detect the dark gaps around the eye region of the mask.

We evaluate the performance of each method by using several metrics such as precision, recall, and accuracy defined in [12]. Table 1 shows that each method can perform well to detect eye blink as the users do not wear glasses. When the users wear glasses with thin rim and thick frame, Krolak is worst among all methods as shown in Tables 2 and 3. This is because Krolak as traditional eye-

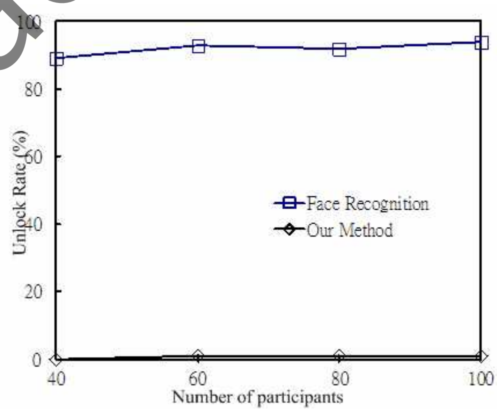


Fig. 9 Unlock rate of face recognition and eye-blink detection under the color photos of the user self

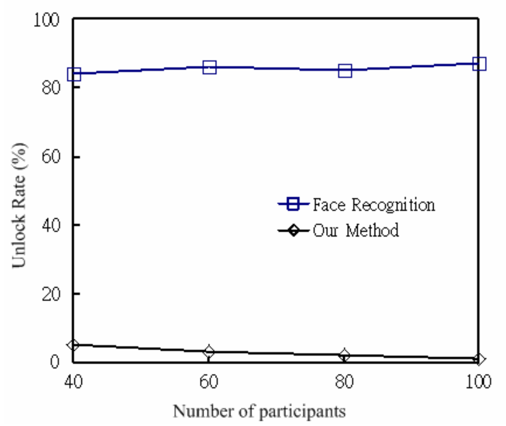


Fig. 10 Unlock rate of face recognition and eye-blink detection under the mask of the user self

Table 1 Performance of eye-blink detection under no-glasses wearing

Method	Precision	Recall	Accuracy
Krolak	92.82	94.17	91.53
REGT	94.03	95.76	92.38
Our method	97.63	99.27	95.88

Table 2 Performance of eye-blink detection under glasses wearing with thin rim

Method	Precision	Recall	Accuracy
Krolak	83.18	85.33	80.47
REGT	95.54	96.91	93.72
Our method	96.81	98.36	94.93

Table 3 Performance of eye-blink detection under glasses wearing with thick frame

Method	Precision	Recall	Accuracy
Krolak	76.04	78.28	74.35
REGT	90.55	91.18	87.49
Our method	94.91	96.23	93.74

blink detections does not consider bright noise and glasses frame over the location of eyes due to glasses wearing. Although REGT yields fair performance under glasses wearing, it is still inferior to the proposed method as demonstrated in Tables 2 and 3. The reason is that the frame difference in REGT cannot effectively filter out the bright noise and the edges of the glasses frame.

4.4 Limitation

The light sources of face images are too bright or dark to recognize in our method. In addition, the facial expression of the user has to be still. Otherwise, the performance of our method is not very well especially for laughing expression. On the other hand, the color of sunglasses wearing is too dark to detect the eye blinking, and this also degrades the performacne of our method.

5. Conclusion

Due to the popularity of smart phone, people tend to store some important information in the mobile phone such as bank information, photos, customer data, and subscription information, and so on. However, when the information was stored in the mobile phone, it will need strong protection methods to avoid the theft of related information by others. Face Recognition can be esaily cheated by using the color photos of the users on the mobile devices. Therefore, in this paper, the eye blink was proposed to improve the face recognition on mobile screen unlocking. Our method did not need any complicated procedure to authenticate user identity, and the user just blinks his/her eyes to fast unlock the screen on mobile devices.

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