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Gaze Based PIN Authentication System

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Abstract—

Personal identification numbers (PIN) have been widely used for user authentication and security since the late '90s. Since PINs can be easily crack-able these days, we prefer to follow a\different approach. PIN authentication with hands-off gaze-based PIN entry techniques, on the other hand, leaves no physical footprints behind and therefore offers a more secure password entry option. PINs (Personal Identification Systems) have been widely adopted worldwide as primary means of secure communication for user authentication and verification purposes. However, it's not a foolproof system since it can be easily forged. Since PINs need to be entered manually, it provides an easy opportunity for an intruder to crack it. Thus , it is susceptible to various intrusions such as shoulder surfing, keylogger, tap print etc. In this paper, an eye pupil movement based PIN generation system has been devised. At first, the user enters sensitive authentication input (PIN) by using eye pupil movements in various directions (i.e., Left, Middle and Right), which further is internally mapped into various patterns of digits from 0 to 9.

Thus, eavesdropping by a malicious observer becomes practically impossible. It utilizes HaarCascade classifier for face and eye detection followed by combined approach of HOG features integrated with SVM classifier for eye blink detection. For pupil detection, canny operator is employed followed by fitting a circle to pupil using circular Hough Transform. Tracking the position of the eye pupil is achieved using a projection function algorithm.

The accuracy of eye detection, eye blink detection and eye tracking are 98%, 92.51 % and 96.25 % respectively. The contribution of this paper is outlined along with a comparative study between proposed approach and traditional authentication systems like gaze, gaze – touch, eye movement CAPTCHA and such graphical image-based authentication methodologies. Our devised system is simple, user friendly and works under low light conditions without involving any significant dependencies on the intricacies of the system.

Keywords—

Personal identification numbers(PINs), Haar cascade classifier, Canny edge detection, hough circle transform, Histogram of oriented gradients, SVM, Eye tracking.

I. INTRODUCTION

Owing to the continuous evolution of technological advancements in recent times, the spectrum of launching intrusions is equally rising worldwide. Thus, the conventional security and privacy systems need to be accordingly adapted worldwide. In today's systems, personal identification numbers (PINs) serve as primary means of communication for authentication of any user for multiple applications.

Throughout history, technology has been the driving force of change. From movable type to television, to the Internet, technology has been embraced and incorporated into our daily lives. Within the constructs of civilized society, the vast rewards of technological innovations have far outweighed the negatives. Unfortunately, common approaches of entering PINs by using an input device like a mouse or a keyboard, are rendered unprotected to intrusions like shoulder surfing, acoustics keyboard eavesdropping [2,3,4] and screen electromagnetic emanations that threaten the security and privacy of the user[5].

One such recent authentication mechanism that has caught the attention of researchers worldwide is the biometric authentication system which is steadily gaining widespread importance and popularity globally. Unfortunately, implementing biometric authentication on an enormous scale is still a challenge. For authentication, a user must be distinctive, quick and accurate for providing secure and widely accepted access. Fulfilment of all these issues is a challenge in itself. Most of the criteria mentioned above depend closely on how people cope up with the emerging technologies and previous works have demonstrated that user interaction with the system has a noteworthy effect on system performance. So, a strong defence system is evidently desirable. In this paper, an eye pupil movement-based PIN generation system is designed. A combination of the biometric modalities with distinct eye pupil movements has been mapped to various patterns in the systems, which offer high resistance to counterfeiting. Each of the Eye movements in various directions (i.e. Left, Middle and Right) will be mapped internally to numbers from 0-9. In this manner, the users can enter the PIN using eye pupil movements that can be completely secure.

The remainder of the paper has been composed in the following manner: Section II depicts literature surveys conducted in the domain of eye pupil movement-based authentication methodologies. Section III denotes the proposed methodology that has been pursued. Next section outlines the detailed experimental results. Finally, Section V concludes the paper.

II. LITERATURE SURVEY

Different researchers worldwide have recently started experimenting and exploring the domain of authentication systems based on eye movements. Some literature surveys related to such ongoing research have been outlined in this section.

Researchers M. Brooks et al. [6] discussed passwords and the problems associated with it that resulted in security vulnerabilities and high economic costs. In the search for alternative potential authentication solutions for the future, biometric authentication systems have become a lucrative solution since such systems are quite simple and don't expect users to recollect any secret. However, biometric authentication also faces significant challenges owing to people's ability and unwillingness in employing this technology. To solve these issues in this paper, an eye movement biometric authentication prototype has been developed. The experiment was conducted in presence of 22 participants and measurement metrics included authentication time, security, acceptability and usability of the proposed system in comparison to its traditional PIN based counterpart. Most participants selected the proposed system as the preferable approach to the traditional PIN based system.

Researcher D. Rosado [7] has explored the video oculography gaze tracking method while inputting passwords in a skilful manner such that shoulder surfing can be avoided. It utilized subject specific gaze parameters with the help of a calibration method; so that no one can forge the password by simply gazing the password. The obtained result showed that this method has lower error rate and higher speed in comparison to the traditional password-based system.

Researchers M. Martin et al. [8] described an eye tracking study of the proposed Image Pass system, which can be considered as a graphical authentication system that is based on recognition. Graphical password has been proposed owing to its better features capacity to perceive and recollect pictures. The aim of the study was to invent the user perception and reaction to graphical authentication. The result revealed visual selection of blind spots and a potential contrast in generic observation patterns between males and females.

Researchers M. Khamis et al. [9] proposed a Gaze-Touch Pass multimodal methodology, which is a combination of gaze and touch for overcoming the shoulder surfing attacks on mobile phones. Gaze-Touch Pass accepts passwords with few switches all through the procedure of authentication. It makes the job of intruders pretty difficult, since attackers require all the while watching the device screen and the user's eyes to deduce the password. Results showed that Gaze-Touch Pass is fundamentally more secure than single modular frameworks, particularly due to its quicker switch focus between phone and eyes. The time taken for authentication was 3.2 sec. So the proposed system was secure and faster than traditional gaze based systems. Researchers Z. Li et al.[10] proposed a system i.e., iType, that utilized eye gaze to type private input on commodity mobile platforms. It faced some challenges like i) low accuracy of tracking the mobile gaze, ii) correction of input errors due to lack of comparison with true text value entry and iii) lastly motion of device and surrounding noise might deteriorate the accuracy of gaze tracking. To overcome the aforesaid issues, some effective methodology has been adopted in this paper, i.e. utilizing a collective behavior of the gaze followed by results, hints of motion sensor coming from mobile devices and distinctive correlation of the typing error. The result showed that iType achieved high accuracy within short latency.

Researchers A. Siripitakchi et al. [11] proposed a new concept CAPTCHA (which is the common method to differentiate between human and machine) based eye movement characteristics, which overcame the CAPTCHA based system attacks. It used gaze detection and eye movement methodology. Here Eye CAPTCHA replaced the existing CAPTCHA. This procedure was used to increase the performance to prevent different types of assaults.

Next section of the paper details our proposed methodology.

III.PROPOSED METHODOLOGY

The main principle of the proposed system is to generate eye pupil movement-based PIN generation systems that are dependent on

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computerized vision technology. It is achieved using different methodologies such as face and eye detection, eye blink detection, rectangular and circular pupil edge detection and eye tracking as shown in Fig.1. The process starts (shown in Fig.2) when the system receives the images captured by USB web camera and thereafter performs face and eye detection by Haar Cascade classifier followed by whether an eye is open or close detection method achieved by eye blink detection with the help of Histogram of Oriented Gradients (HOG) algorithm. After that, the target is to detect the rectangular and circular edge of the eye pupil by canny edge detection and Hough Circle Transform (HCT) scheme respectively. For this purpose, the eye region of interest is cropped and all the possible circles of that respective space are detected which will detect the eye pupil accurately. Next using coordinate system logic, the distance between the centre point and eye pupil centre point can be measured and the distance gets varied as per the eye pupil movements. Eye pupil left position is represented by minimum distance, whereas the right position is represented by the maximum distance and no movement of eye pupil is equal to middle position. These positions i.e. Right, Left and Middle can be mapped into 0 to 9 digits by different patterns. This can be further used as PIN by eye movement.

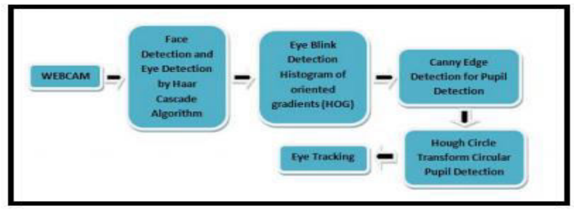

Fig. 1. Proposed System

A. Face detection

For face detection [12] a set of templates are used for extracting the Haar – like features as shown in Fig 3. But all features are not required for face detection.

Thus, a boosting algorithm [13] is utilized to locate the finest features that can be utilized for differentiating a picture into a face or a non-face image. In this algorithm to develop a cascade classifier only selected features are used and by this way few classifiers are cascaded and form the viable classifier.

Every phase of the cascade classifier verifies the specific number of features. If an image region contains a face then it proceeds into the second phase else it is rejected. Similar phenomenon occurs for all stages. A face is detected only if an image qualifies in all the stages of the classifier.

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B. Eye Region Extraction

The extraction of the eye region is done by the geometry ratio of the face. If h signifies the face height, then from that point the eyes are put between the separations 0.2h to 0.6h from the highest point of the head as shown in Fig.4.

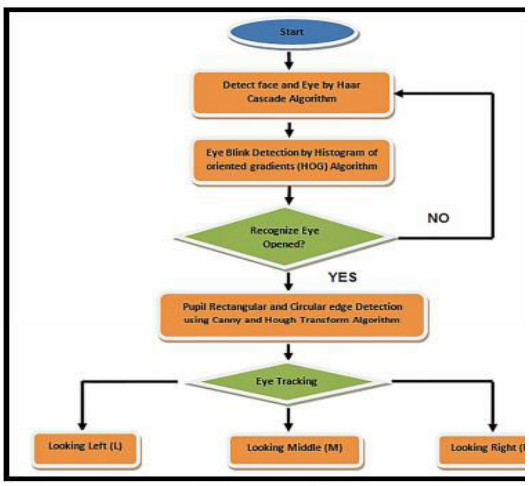

Fig. 2. Proposed Process

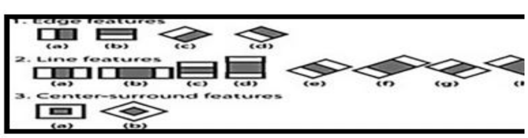

Fig. 3. (a) Edge Features (b) Line Features (c) Rectangular Features

Fig. 4. Geometric Ratio of human eye

C. Eye Detection

After extraction of the eye region, the Haar Cascade classifier is used for eye detection. Cascade classifier training is conducted over eye images as it is executed in the face detection process. The eye region is categorized into two portions by the trained classifier: one which contains an eye and another which does not have an eye. In any case, this methodology fails when the eyes are shut. For this reason, an eye blink detection method is required.

D. Eye blink detection

The feature descriptor algorithm, HOG, is utilized for eye blink detection. The methodology works by calculating the event of the direction of the gradients in the images, which are termed as cells. This sums up an image with the goal that a similar picture creates a similar feature descriptor close to conceivable along these lines making the work of classification simpler. After obtaining the eye image from the previous section, the HOG features are extracted.

The eye pictures are first reconstructed into 24×24-pixel size followed by separating it into squares. At that point each square is separated into four similarly estimated cells with every cell size 8×8 pixels as shown in Fig. 5.

Fig. 5. Cells (Yellow Squares), Overlapping Squares (Blue and Red Squares)

After that each cell values are extracted by Sobel Filters, which is given in the equation below:

Horizontal filter, FX = [-101] (1)

Vertical filter, FY = [-101] (2)

The gradient vector's magnitude and orientation are calculated by the equation below:

Magnitude: s = Square root of [(FX) 2 + (FY) 2] (3)

Orientation: θ = arctan (FY / FX) (4)

When these values give HOG features values from every cell and the total number of values obtained is 144. These 144 feature values are used in the SVM classifier for identifying the open eye class and close eye class.

E. Support Vector Machine

It is a supervised strategy that uses Gaussian Radial basis function as the kernel. In this methodology, the focus is to discover the decision surface, which separates the two classes [14]. Here hi (I =1….l) represents the feature vectors and ci = ± 1 defines the two classes. It discovers an improved hyper plane w. h + b = 0 that isolates the two classes. When w and b is optimum then margin is maximum.

F(h)=sign of summation over (I =1…l)[αi ci K(hi h)+b] (5)

Here α i (i= 1,….l) symbolizes Lagrange multipliers , αi and b are identified by a learning algorithm and hi is calculated by SVM.

F Rectangular Pupil Edge Detection

To identify the rectangular edge of the pupil, a canny edge detection algorithm is used. For this purpose, a canny edge detector applies two thresholds to the gradient. One of them is a higher threshold for identifying a lower sensitivity edge and lower threshold used for a higher sensitivity edge. It has 5 separate phases:

- Smoothing: This scheme removes the noise obscuring the image.

- Finding gradients: Canny algorithm is used when the grayscale intensity of the picture is changed to discover the edges. For this purpose, the Sobel operator determines the gradient of that image. The magnitude of the gradient can be calculated by Euclidean distance in equation (3) and simplified version is defined by applying the Manhattan distance in the images as shown in equation (6) .

$|F| = |F_x| + |F_y|$ (6)

Here, the gradients in x and y directions are defined by Fx and Fy respectively. The magnitude of the gradient determines the edges, yet, these edges are ordinarily expansive and don't give the specific area of the edges. To overcome this problem, we use equation (4).

- Non-maximum suppression: This changes the blurred edges into sharp edges for storing all local maxima in the gradient image by eliminating all the irrelevant details

- Double Thresholding: Potential edges can be determined by double thresholding. In this procedure, the pixel that has greater value than high threshold is marked as strong edge, whereas the pixel that has lower value than low threshold is marked as weak edge.

- Edge tracking by hysteresis: After thresholding, the strong edges are included in the final edge of the image, whereas weak edges may be included if they are connected to the strong edges.

G. Circular Pupil Edge Detection

After rectangular edge detection is performed to detect the circle of the eye pupil, the HCT scheme is used. In comparison to line, it is easy to represent the circle with respect to parameter space, because the parameter of the circle gets directly mapped to the parameter space [15]. Circle can be represented by: (x-a)2 + (y-b)2 = r2 .

To find the circle of the pictures using HCT, first the edge is detected using the Canny Edge Detection scheme. This circle is drawn in the parameter space, where x axis has value, y axis has b -value and z axis has radius r. At the coordinates, which have a place with the perimeter of the drawn circle, the

accumulator matrix value is increased. Now the accumulator contains the number of circles experiencing the individual coordinates. One or several maxima (highest numbers corresponding to the centre of the circles in the image) are then searched in the accumulator. Once detected, the discovered parameters (r, a, b) are mapped compared to the maxima back to the original picture.

H. Eye Tracking

Projection function algorithm is used for Eye Tracking, where a coordinate system is used for locating the Eye pupil centre. In fig.6 the location of the eye pupil in the coordinate graph is depicted, where the horizontal and vertical axis determines the left and right eye pupil movement direction. The relation between eye pupil centre and respective projection points is determined by the projection function graph, where X and Y point determine the eye pupil movement direction.

The actual (A0, B0) coordinate point is determined by equation 9 and 10:

A0= (A1+A2) /2 (9)

B0= (B1+B2)/ 2 (10)

Here X direction corner point of the eye pupil is A1 and A2 whereas Y direction corner point is denoted by B1 and B2. The X and Y calibration point present the eye movement direction. The actual eye position can be determined by (A0, B0) coordinate point.

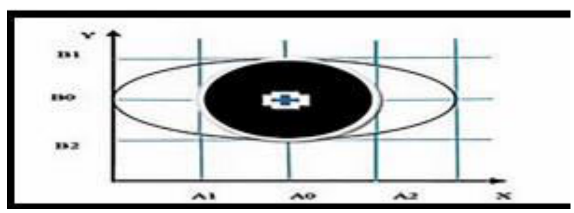

Fig. 6. Coordinate system is used for locating the Eye position

These left, right and middle combinations are mapped into 0 to 9 digits, which is further used as a PIN. The mapping pattern is depicted below in Table I.

The next section outlines the achieved experimental results.

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IV. EXPERIMENTAL RESULTS

It was performed using Python IDLE 3.6.4. The Webcam captures the image frames. After this, the face is detected as described in section A. The classifier arranges the image frames into two parts which contain face and non-face. The segment that contains the face is extracted by this way. Sample image of the face detected is shown in Fig 7.

TABLE I. EYE MOVEMENT PATTERN MAPPING INTO DIGIT

Eye Movement	Eye Wait	Eye Movement	Eye Wait	Looking Left	Ma O
Looking Left	3sec Wait	Looking Left	3sec Wait	Looking Left	
Looking Right	3sec Wait	Looking Right	3sec Wait	Looking Right	
Looking Middle	3sec Wait	Looking Middle	3sec Wait	Looking Middle	
Looking Left	3sec Wait	Looking Left	3sec Wait	Looking Right	
Looking Left	3sec Wait	Looking Right	3sec Wait	Looking Left	
Looking Right	3sec Wait	Looking Left	3sec Wait	Looking Left	
Looking Right	3sec Wait	Looking Left	3sec Wait	Looking Right	
Looking Left	3sec Wait	Looking Right	3sec Wait	Looking Right	
Looking Right	3sec Wait	Looking Right	3sec Wait	Looking Left	
Looking Middle	3sec Wait	Looking Right	3sec Wait	Looking Left	

Fig. 7. Face captured by Webcam and detection by Haar cascade classifier

Then the geometrical characteristics of the face is calculated with the help of eye region extraction. These proportion and extracted eye area is sent to the eye detection phase by Haar based Cascade classifiers shown in Fig.8 whose accuracy is 98% given in Table II.

Fig. 8. Extracted Eye Region and Eye detection

TABLE II. EYE DETECTION ACCURACY

Data Set	Total No. of Images	No. of Eye Images Detected Correctly	Accuracy
In- Built	300	294	98%

For detecting whether the eye is open or closed, 144 HOG features of eye pictures are extracted. These are applied to the SVM classifier, which then identifies whether the eye is open or closed. There are 294 eye images in the experiment, which consists of 147 open and 147 closed eyes. The experiment shows in Table III that the accuracy to detect open and closed eyes is 92.51%.

TABLE III. EYE BLINK DETECTION ACCURACY

Data Set	Total No. of Eye Images	No. of Correct Classifications	No. of wrong Classifications	Accuracy
In-Built	294	272	22	92.51%

For detecting the rectangular edge pupil here, canny operator is used, which is depicted in fig. 9 and for detection of the exact circular region of pupil, Circular Hough Transform (CHT) is used. For this reason firstly, among all circles some of the biggest circles are selected with the help of CHT, followed by picking a circle whose center is closest to the approximate center instead of different circles as shown in fig. 9. For calculation of the distance between them, Euclidean distance is used, which is expressed by equation (11). Dist (ef,ee) = Square root (xef + xee) 2 + (yef + yee) 2 (11)

Fig. 9. Rectangular Pupil detection and CHT boundary box of pupil area

Here ef (xef , yef) represents the pupil center coordinate, whereas cc(xee , xee) denotes circle center coordinate. After computing the Euclidean distance, the closest circle found by CHT is fitted into the pupil and Fig.10 demonstrates the obtained experimental results.

Fig. 10. Circular Pupil Edge Detection by Hough Transform

After exact detection of the eye pupil, the center is calculated and by using the eye tracking algorithm (as mentioned in section H) the Right , Left and Middle position are computed as given in fig.11 and the accuracy of the eye tracking method is 96.25 % given in table IV. Then these eye movements are mapped into different patterns to find out the 0 – 9 digits as shown in fig.13. The overall Performance accuracy in terms of eye ,

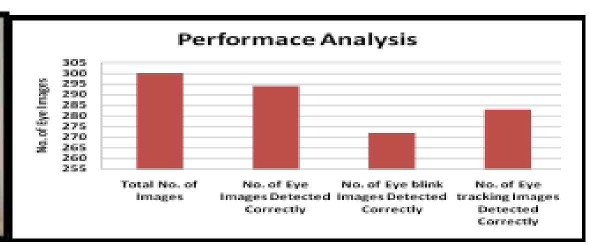

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Fig. 11. Eye Movement on Right, Middle and Left eye blink and eye tracking detection is represented in Fig. 12.

Fig. 12. Performance analysis of proposed methodology

TABLE IV. EYE TRACKING DETECTION ACCURACY

Data Set Total No. of Eye Images Correctly Detected in Eye tracking Accuracy

Data Set	Total No. of Eye Images	Correctly Detected in Eye tracking	Accuracy
In- Built	294	283	96.25%

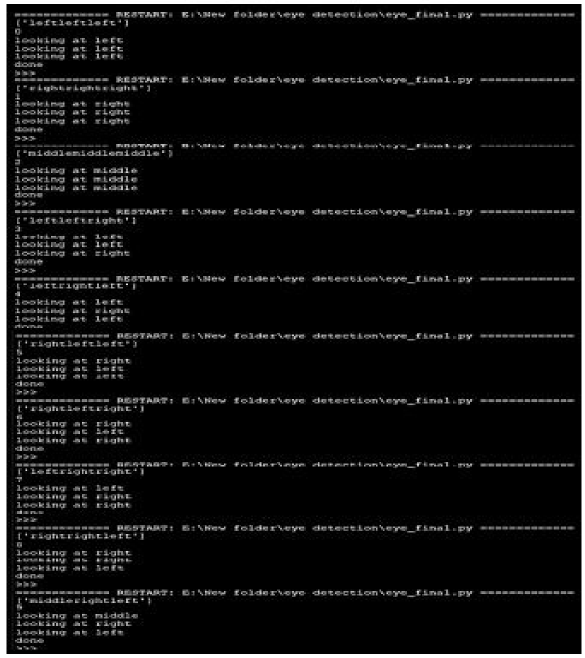

Fig. 13. Eye Movement Mapped into digit

V. CONTRIBUTION

There are several systems available such as traditional gaze, gaze -touch, eye movement CAPTCHA and Graphical Image based authentication systems. Gaze based systems suffer from problems due to inadvertent eye and body movements that may prompt wrong gaze points and inaccurate password entry.Gaze and touch based may have iterative attacks and minimize the system performance for varying light conditions. CAPTCHA based systems are not user friendly, whereas Graphical Image based may be hard for potential users to get a handle on the complexities of the framework and find the correct alternatives to accomplish their tasks and objectives. The proposed eye pupil movement based PIN generation system in this paper offers the following benefits:

i) It is simple and very user friendly since it uses simple coordinate geometry with a projection function algorithm.

ii) It works well even under unfavorable circumstances like in low light conditions.

iii) It does not depend on any complicated intricacies of the system.

iv) It offers high accuracy of eye tracking i.e. 96.2%.

VI. CONCLUSION

In this paper, an eye pupil movement based PIN generation system is devised. It utilizes a process that involves Haar Cascade classifier for face and eye detection and an integrated approach of HOG and SVM classification for eye blink detection. For rectangular edges pupil detection, Canny and Circular Edge Detection is used. Finally the position i.e Right, Left and Middle of the eye pupil is detected by using some eye tracking techniques with the help of projection function algorithm. According to eye pupil position of user, in various directions (i.e. Left, Middle and Right) will be mapped internally to numbers from 0-9. In this manner, the users can enter the PIN using eye movements that can be completely secure. e. The accuracy of the eye detection algorithm is 98%, whereas the success rate of detection of whether an eye is open or closed is 92.51%. Finally, the contribution of this work is outlined and a comparative study is conducted between devised systems and traditional gaze, gaze – touch, eye movement CAPTCHA and Graphical Image based authentication systems.

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