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Graphical User Authentication System Resistant to Shoulder Surfing Attack

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

User authentication is one of the most significant issues in the field of Information Security. The most common and convenient authentication method used is the alphanumeric password which has significant drawbacks. To overcome the vulnerabilities of traditional methods, graphical password schemes have been developed as possible alternative solutions to text-based scheme. A potential drawback of graphical password schemes is that they are more vulnerable to shoulder surfing than conventional alphanumeric text passwords due to their visual interface. To overcome the shortcoming of existing graphical password schemes this project focuses on developing a graphical authentication system that is resistant to shoulder surfing attack.

Keywords: Graphical password; shoulder surfing; password space; password entropy.

1. INTRODUCTION

User authentication is one of the most significant issues in computer and information security [1]. Currently, the most prevalent and well-established authentication approach is based on the use of alphanumeric passwords. The known weakness of traditional user authentication is a

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tendency to choose passwords with predictable characteristics, which in turn reduces password strength and makes it vulnerable to various attacks [2]. To address the problems with traditional username-password authentication, alternative authentication methods, such as token and biometrics, have been used. However, token based systems such as smartcards or electronic-key can be lost, impersonated, stolen or misplaced. Biometrics authentication offers conceptual advantages when compared to the traditional use of passwords or PINs. But users tend to resist its usage because of their intrusiveness and the effect on their privacy. Moreover, biometrics process is slow, expensive and cannot be revoked. Graphical authentication has been proposed as a user-friendly alternative to password authentication [3], Wiedenbeck et al. 2005. A graphical password is an authentication system that works by having the user select from images, in a specific order, presented in a graphical user interface (GUI). A potential drawback of graphical password schemes is that most of the current graphical password schemes are more vulnerable to shoulder surfing due to their visual interface [4,5] Wiedenbeck et al. 2005.

1.1 Aim and Objectives

The aim of this research is to design and implement an efficient graphical password resistant to shoulder-surfing attack to improve security in user authentication.

The objectives are:

- To design and implement a new authentication mechanism with balanced security and usability features.
- To test the developed system in an environment prone to shoulder surfing attack.
- To evaluate the developed authentication system against the existing authentication techniques.

2. LITERATURE REVIEW

Graphical Password as defined by Yokota et al. [6] is: “an authentication system that works by selecting or drawing images, by users in a specific order, presented in a graphical user interface (GUI). Graphical Authentication Techniques are categorized into three groups:

- Pure recall based.
- Cued recall based.
- Recognition based.

2.1 Pure Recall Based Techniques

In pure recall-based techniques, a user is asked to reproduce something that he or she created or selected earlier during the registration stage without any hint provided by the system. Examples of pure recall based technique are Passdoodle, Draw a secret, grid selection algorithm, qualitative DAS algorithm etc.

2.1.1 Draw a secret (DAS) algorithm

In 1999 Jermyn et al. proposed a new graphical password scheme called Draw-a-Secret algorithm. It is a typical implementation in which user draw a design on the grid using mouse or stylus. This method consisted of an interface that had a rectangular grid of size G * G, which allowed the user to draw a simple picture on a 2D grid. Goldberg in his 2002 survey concluded that the majority of users could not remember their stroke order [7]. Another weakness is that users tend to select extremely weak graphical passwords which make this authentication scheme predictable and susceptible to various attacks [8].

2.1.2 Grid selection algorithm

In 2004 Thorpe and Oorschot proposed a new graphical authentication scheme that is called Grid selection algorithm to enhance security [9]. A user chooses a smaller grid for drawing within a larger selection grid. Then the user zooms in this piece of grid and creates a drawing like in original Draw-a-Secret (DAS) scheme. This technique of authentication dramatically increases the password space [10]. Whilst this method significantly increases the DAS password space, it however introduces additional job to memorize and time to input the password. In other words, the security enhancement is achieved by sacrificing password usability and memorability [11].

2.2 Cued Recall-Based Techniques

In this technique, the system provides a framework of reminders, hints and gestures for the users to reproduce their passwords selected during Registration phase. Examples of cued recall based techniques are Blonder, Passlogix v-Go, PassPoint, pass-Go, Passmap etc.

2.2.1 Blonder algorithm

Blonder algorithm was proposed by Greg E. Blonder in 1996. During the registration the user is presented with a pre-determined image on a visual display so that the user can point to one or more predetermined positions on the image (tap regions) in a predetermined order as a way of pointing out his or her authorization to access the resource. At authentication phase the user has to click on previously selected locations on the image or close to those locations. The image acts as a hint for the user to recall graphical passwords and therefore this method of authentication is considered more convenient than unassisted pure recall-based schemes (Wiedenbeck et al). The major problem of this scheme is that the number of predefined click regions is relatively small as such the password has to be long for it to be secure.

2.2.2 Passpoint algorithm

PassPoint was created in 2005 in order to improve upon the shortcomings of the Blonder Algorithm. In this method the image could be any natural picture or painting but at the same time must be rich enough so as to have several possible click points. The existence of the image helps the user to remember the click point. The authentication process involves the user selecting several points on picture in a particular order. When logging in, the user clicks close to the selected click points, within some (adjustable) tolerance distance, for instance within 0.25 cm from the actual click point [12]. The login time, in this method, is longer than in the alphanumeric method [12]. Also the user has more difficulty in learning and memorizing in their password. So, users have to go to several trial sessions for completing the process [13].

2.3 Recognition Based Techniques

In recognition-based techniques, users select pictures, icons or symbols from a bank of images. During the authentication process, a user is authenticated by challenging him/her to identify one or more images he or she chooses during the registration stage. Examples of recognition based technique are Passface, Déjà vu, Triangle, story, WIW etc.

2.3.1 Story algorithm

Story Scheme was proposed in 2004, this scheme categorizes the available pictures into nine categories namely animals, cars, women, foods, children, men, objects, natures and sports [14]. Users have to select their passwords from the mixed pictures of nine categories in order to make a story easily to remember (Darren et al. 2004). Research showed that the story scheme was difficult to commit to memory in comparison to pass face authentication [15].

2.3.2 Triangle algorithm

Sobrado and Briget [5] introduced an algorithm to overcome the problem of shoulder surfing attack named Triangle. This scheme randomly places a set of N objects (a few hundred or a few thousand) on the screen. Additionally, there is a subset of K pass objec*ts* previously chosen and memorized by the user. The system will select the placement of N objects randomly in the log-in phase. The system initially chooses a patch randomly covering half the screen, and then randomly again places the K password objects in that patch. In the log-in phase, the user must be able to find the location of three pass-objects and then click inside the invisible triangle that is possible to create those three objects. But, for each login this process will be repeated using a different group of n objects. The disadvantage of this algorithm is that the log-in phase must use a minimum of 1000 images in order to resist shoulder surfing attack. As a result too many objects are displayed, making it harder for the users to pin point the pass-objects while too few objects makes the password space small and hence become simpler to predict or hack [16].

3. METHODOLOGY AND DESIGN

3.1 System Description

The system uses a combination of Draw a Secret (DAS) and Story algorithms. Users are instructed to mentally construct a story to connect their selected images to aid memorability. It requires users to draw a curve across their password images (pass-images) orderly rather than directly clicking on them. The curve drawn by the user passes through both pass-images and decoy images, which is used to confuse peepers. The drawing begins and ends with given random images to avoid exposing the first and the last pass-images. The drawing trace is cleared off as the user draws the curve which reduces the probability of passwords being exposed. In addition, random curves are displayed as user draws a curve across pass images. The system

displays degraded images at the login phase which are difficult to distinguish from a distance or from a side view

4. RESULT

4.1 Security Test and Evaluation

The two methods of evaluating security in GUA algorithms are password space and password entropy. One of the methods "Graphical Password Space" is defined and a comparative table between some previous algorithms and the newly proposed algorithm is generated. The second method "Graphical Password Entropy" is also defined and a comparison between some previous algorithms and newly proposed algorithm represented in a table is generated. The system is also tested against shoulder surfing attack and a comparative table is used to compare the result of the proposed system with previous algorithms.

4.1.1 Shoulder surfing attack test

A user study was conducted to test the effectiveness of the proposed method in reducing shoulder-surfing attack. Thirty participants were involved in carrying out the shoulder surfing attack; 16 of them were male, while 14 of them were female. Shoulder-surfer intent is to steal authentication information by either looking over the victims' shoulders or recording user authentication process using camera, recruiting a participant group that would represent the true population was practically impossible. However, a participant group with authentication system experience was deemed appropriate to represent "potential shoulder surfers," as they use password-based logins on a daily basis and are conversant with authentication in general.

Half of the participants were assigned to the Attacker group and the remaining half to the Victim group. Participants in Victim group consist of registered users i.e. users that are already familiar with the authentication system. The Attacker group participants were briefly introduced to the scheme. They received a short training session after the introduction on how the authentication system is used. Subsequent to the training session, the Attacker group participants were instructed to act as an attacker using 'shoulder-surfing' method to acquire user password. In order to gain access to the system through shoulder-surfing, participants from the Attacker group were given "optimal" shoulder-surfing conditions in which they had the choice to sit next to the person (victim group participant), entering their password or to stand behind them. Attacker group participants had the liberty to record authentication process using camera or move from one side to the other depending on how they felt the most comfortable trying to obtain the "victim group participants" password.

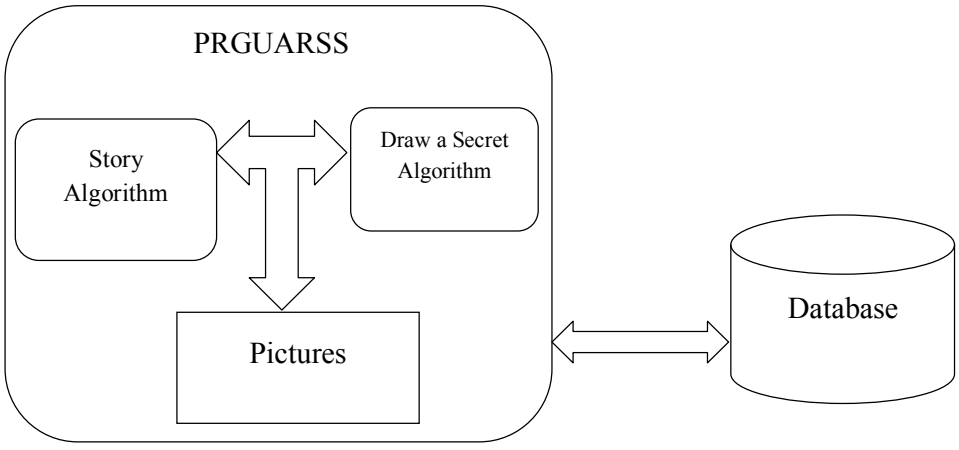

Fig. 1. Architectural design of the system

Fig. 2. Screenshot of pass pictures selection page for Registration

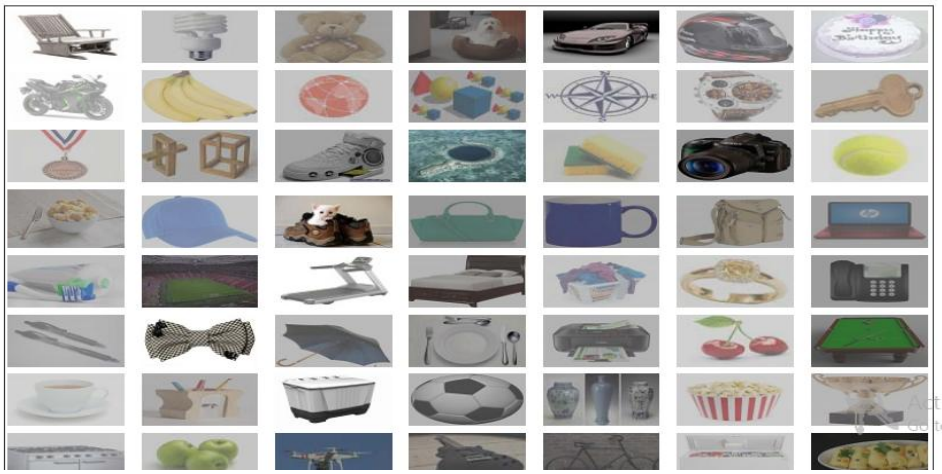

Fig. 3. Screenshot of pass pictures selection for login page

4.1.1.1 Result

The shoulder-surfing test resulted in none of the participants from the attacker group being able to discover users password because random pictures are displayed at each of the three login rounds, it was difficult to know which of the three rounds contains correct order of user passimages, the random curves displaying as user draws a curve was distracting making it difficult to track the curve pattern, it was difficult to follow user drawing trace because the trace cleared off as user draws and only the tail part is left to show the current location of the mouse. Attacker group participants were given five trial attempts to guess the password used. The results of the shoulder-surfing test in the user study indicate that the proposed system is resistant to shoulder-surfing attacks, despite the fact that the attackers know how the proposed system and the underlying algorithm work. The table below shows the result of the five trial attempts of the participants.

Table 1. Result of Participants' shoulder surfing attack trial

Participants/ trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The strategy used by the participants to obtain the password was inquired. 33.3% of the participants stated that they applied direct observation method and repeated some of the pictures selected by the victim, while 13.4% of the participants selected pictures in the exact identified location victim selected his/her pictures. Other participants (53.3%) selected pictures randomly in the challenge set because they did not have any hint as to which picture is the pass or decoy images.

4.1.2 Graphical password space

Password space is the number of options in the scheme available to users for choosing a password. It is not possible to define a formula for password space but for all algorithms it is possible to calculate the password space or the number of passwords that can be generated by the algorithm. Some of the previous algorithms and the proposed system password space are calculated and a comparative analysis of the algorithms is made.

4.1.3 Graphical password entropy

Password entropy is usually used to measure the security of a generated password, which conceptually means how hard to blindly guess out the password. In other words, Graphical password entropy tries to measure the probability that the attacker obtains the correct password based on random guessing. Password entropy of a graphical password can be calculated as:

$$\text{Entropy} = \mathbf{N} \log_2 (|\mathbf{L}||\mathbf{O}||\mathbf{C}|)$$

N is the length or number of runs, L is locus alphabet as the set of all loci, O is an object alphabet and C is color of the alphabet.

Table 2. Comparative table of existing algorithms and prguarss based on their resistant to shoulder surfing attack

Name of author or scheme	Resistant to shoulder surfing
Blonder (Blonder 1996) [17]	No. Because users' actions are captured easily by clicking directly on the image.
Draw-A-Secret (DAS) [18]	No. Because users re-draw their pattern on the same grid.
Syukri, Okamoto and Mambo (Syukri et al. 1998)	No. Because attacker can easily capture users' actions through the use of video capture device.
Pass Point (Birget et al. 2003)	No. Because the attacker can use a video capture device to record user's action and gain user's password.
Déjà vu [4]	No. Because user clicks directly on the image which makes users' actions easier to capture.
Picture Password (Jansen et al. 2003)	No. Because users' actions can be easily captured since users click directly on the image.
Triangle	No
Movable Frame	No
Story password	No
WIW	No
Proposed System (PRGUARSS)	Yes

Result versus existing algorithms:

Table 3. Comparative table of prguarss and previous algorithms based on graphical space

Algorithm	Formula
Textual (with 6 characters length include capital and small alphabets)	52 ^ 6
Passface (4 rounds, 9 pictures)	9 ^ 4
Story (4 rounds, 9 images)	9 ^ 4
Picture password (30 images, 4 rounds)	30 ^ 4
DAS (represented on 5*5 grid with 6 strokes)	25 ^ 6
Triangle (100 picture objects with 3 registered objects)	100 ^ 3
Blonder (4 pixels and assuming 30 salient points)	30 ^ 4
PassPoint (5 number of pixels with 30 locations to be clicked)	30 ^ 5
PRGUARSS (select 5 images from 70 images, and 3 rounds in Log-in phase)	(70*3)^5

Result versus existing algorithms:

Table 4. Comparative table of prguarss and existing algorithms based on password entropy

Algorithm	Formula	Entropy (bits)
Textual (with 6 characters length include capital and small alphabets)	6 * Log2 (52)	34.32
Passface algorithm (4 runs, 9 pictures)	4 * Log2 (9)	12.68
Picture password (30 images, 4 rounds)	4 * Log2 (30)	19.63
Story (4 rounds, 9 images)	4 * Log2 (9)	12.68
DAS (represented on 5*5 grid with 6 strokes)	6 * Log2 (25)	27.86
Triangle (100 picture objects with 3 registered objects)	3 * Log2 (100)	19.93
PassPoint (5 number of pixels with 30 locations to be clicked)	5 * Log2 (30)	24.53
Blonder (4 loci and assuming 30 salient points)	4 * Log2 (30)	19.63
PRGUARSS (select 5 images from 70 images, and 3 rounds in Log-in phase)	5 * Log2 (70*3)	40.28

The results from the test and evaluation based on usability and security features demonstrated that the proposed system is more secure when compared with previous algorithms. Finally, the result of test and evaluation shows that the proposed system not only covers the usability features but was also more secure in comparison with other algorithms. In other words, the algorithm is successfully balanced the usability and security features.

5. CONCLUSION

This project presents a web based GUA system combining recognition based (Story) and pure recall based (Draw a Secret) graphical password to prevent shoulder surfing attack. The main contribution is that it overcomes a shortcoming of recall-based systems by erasing the drawing trace and introduces the drawing method to a variant of Story to resist shoulder-surfing attack. The result of the three categories of evaluation indicates that PRGUARSS performed very well, beyond the shoulder-surfing resistant properties of the system, it also covers the usability and security features. It means the PRGUARSS provides a good balance between usability and security features in GUA algorithms. Therefore, the system can be run as Login part on all secure websites such as Bank, Police, Companies, Universities and Schools.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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