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Authentication System for Sessions using Graphical PIN Entry

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Abstract*—Information and computer security is supported largely by passwords which are the principle part of the authentication process. Authenticating by entering a PIN (numerical password) is the most common authentication technique these days. ATM, Mobile application passwords, POS terminals, electronic door access system, etc. mostly use PIN as their authenticating mechanism. As these passwords are to be typed in frequently and always in a hurry, their length is too small and hence, any person or camera can easily scan them and make a note of it. This makes it too unsecure as they are highly hack able. Shoulder surfing attack is the most common type of hacking attack among these types of hacks. The authentication system we are proposing here is resistant to shoulder surfing attack because for every login session, the password will be different. In Graphical Pin Entry technique, for entering the PIN, we have used some extra information such as reference location which when combined with a secret pin password and a username provides a better resistance against the shoulder surfing attack. We are assuming that the registration is done in a secure location where no other person or the video recording device is present and hence, the attacker is unaware of the secret pin password and the reference location. During registration, user will provide a username, a pin password and the reference location co-ordinates of the matrix. Now, the reference location and the pin password is unknown for the attacker and while entering the password we will not be entering the pin directly! We will enter the pin using a reference location in an indirect graphical way and this will be called as our session password. The session password will be different each time and the user will be able to identify it using the matrix that we will be showing on the user interface. So, even if the attacker sees the user while graphically entering the password, that will be a session password which will be of no use to the attacker as it will be different every time!We have implemented the prototype of the proposed authentication scheme using DotNet compliant C# language and conducted a user study to evaluate the usability of our proposed authentication system. The results of the user study show that this scheme has a great balance between securities, usability, feasibility as is resistant to a shoulder surfing attack which may be a naked eye based attack or the video recording based attack. Our technique also provides a resistant to brute force attack, dictionary attack and random password guessing attack.*

Keywords*—Authentication, shoulder surfing attack, graphical pin entry*

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I. Introduction

Current authentication system suffer from many weaknesses. The vulnerabilities of the textual password have been well known. Password possess many useful properties as well as widespread legacy deployment; consequently we can expect their use for the foreseeable future. Thereexistsmany authentication schemes which are used to authenticate users for different purposes. In this paper, our focus is on PIN based authentication techniques. PIN based authentication systems are widely used authentication techniques [1]. The huge user acceptance, usability and feasibility of PIN based passwords is highly dependent on its easy to use mechanism. They are too simple as they have a limited set of only digits from 0 to 9. The password length is also short, generally 4 to 6 digits long. Dueto limited characters granted for use in the password and minimal password length, the errors are also low [2].

The consideration of Personal Identification Numbers (PIN) based authentication systems from the security point of view exposes that its straightforwardness affects its security badly. Different kinds of PIN entry systems are vulnerable to different types of attacks, for example, random guessing attack [3] and the most common, the shoulder surfing attack. In order to lessen the threat of brute force attack, the number of attempts for unsuccessful login may be restricted to a minimum number such as 3, 4 or 5. However, the shoulder surfing

attack is quiet a big challenge for different authentication patterns.

Shoulder surfing attack is a method used to find the information like personal identification number (PIN), passwords and other private data by observing over the user's shoulder. The simplest example of shoulder surfing attack is a person standing directly behind a person in a row of an ATM machine while the victim is typing the PIN. He can easily look over the shoulder of a person to grab his PIN. Same situation applies when someone isputting his PIN, pattern, or the password while unlocking asmart. Surveillance cameras may also assist a shoulder surfer in noting the PIN, pattern, or the password of a user.

The inspiration behind this work is to enhance a PIN entry scheme that improvesthe resistance against the shoulder surfing attack. Hence, this will increase the security and relief level of the users. It is a well-known fact that shoulder surfing attacks exists, but very often are not taken seriously by the users [4]. It is actually stressed that the shoulder surfing is an important form of hacksand are of great concern. In many cases, users have same pin across multipledevices/websites [5].

In this paper, we have proposed a new graphical Personal Identification Numbers (PIN) entry scheme that provides resistance against human shoulder surfing attack and slightly against recording-based shoulder surfing attack. Lee in [6] has stated that it is hard to cater recording based shoulder surfing attack as some of the information in the login process is not unseen from the attacker.

II. Literature survey

Since the last two decades, there is a lot of research to deal withthe shoulder surfing attacks in different kinds of authentication systems. Especially after the extensive use of smart phones. To address such kind of problems, some researcher have developed authentication methods.

Title:A pin-entry method resilient against shoulder surfing
Author:V. Roth, K. Richter, and R. Freidinger
Year: 2004
Roth [7] suggested a PIN based entry method that resistsagainst the shoulder surfing attack but to a limited extent. This technique divides the keypad into two color keys, black and white. The color distribution is random. Depending on the set to which the digit of the PIN under verification belongs, the user enters the key with the same color as the set. For entering a single digit, you must go through 4 rounds of PIN (Personal Identification Number)password entry andin the same way for a 4 digits PIN password, you will need to go through 16 rounds of PIN entry. Two out of three different variants of this authentication techniques are not robust against recording based shoulder surfing attack. But, the third variant is strong against shoulder surfing attack, only if the attacker do not have more than one records of the full authentication step.

Title:A rotary pin entry scheme resilient to shoulder-surfing **Author:**P. Shi, B. Zhu, and A. M. Youssef
Year: 2009
Another PIN based password authentication technique was suggested by Shi [8] in which the designer displays a set of L (number of digits present in the password) co-centered rotating wheels each of which is equally divided into 10 sectors. Each sector is represented with a digit that is randomly nominated from the digits, 0 to 9. Each digit is displayed only once within each circle. Circles can be rotated in clockwise or anticlockwise motion. To enter the PIN, the user needs to align all PIN digits along one sector in the precise sequence. But, this scheme is not strongwhen it comes to the camera based shoulder surfing attack.

Title: Illusionpin: Shoulder-surfing resistantauthentication using hybrid images
Author:A.Papadopoulos, T.Nguyen, E.Durmus, and N. Memon
Year: 2017
Illusionpin [9] is another PIN based authentication technique which resists the shoulder surfing attack. It is based on the virtual keypad in which the author has utilized the technique of hybrid image to mix the images of 2 keypads, a user keypad and a hacker's (shoulder surfer) keypad, with different digits ordering to create a final hybrid image for the virtual keypad. It is assumed that the user is close to his screen all the time as compared to the hacker. If the user views the hybrid keypad from a shorter distance, he will see user keypad. While the hacker who is looking at the keypad from far away will see a different keypad, the shoulder surfer keypad. Moreover, the digit ordering of user keypad also changes with every authentication attempt so that the shoulder surfer will not be able to note the digit arrangementin the user's keypad. In this system, the author has assumed that a shoulder surfer is standing at a certain distance from the user screen which is not always true.

Title: Steganopin: Two-faced human-machine interface for practical enforcement of pin entry security
Author:T. Kwon and S. Na
Year: 2016
Steganopin [10], one of the idea dependent on presenting a challenge response via a UI is also a pin entry

mechanism. The UIhere consists of two keypads. Keypad-1 is a standard and open keypad while the keypad-2 is a random and hidden from the opponent. The user hides the hidden keypad from the attacker by usinghis hands. On the hidden keypad, the user will examine all the digits of his long term pin code to input the required digit on to the open keypad. For every login session, the user needs to enter a new pin on the open keypad considering his long term pin. The new or session pin is also known as the OTP or one time pin. The hidden keypad is not at all visible to the hacker/attacker and hence, the long term pin cannot be hacked with the OTP. The password here cannot be hacked even if the hacker obtains many recording of the authentication process from start to end. But, in this technique, the user has the responsibility of hiding the main password, or the long term password with one of his hand and also using the other hand, enter the password on the open keypad. Hence, a lot of physical effort involved for the user in this technique which makes it a hectic process.

Title: Authentication Schemes for Session Passwords using Color and Images
Author:M Sreelatha, M Shashi, M Anirudh, Md Sultan Ahamer, V Manoj Kumar
Year: 2011
Pair based authentication and the hybrid textual authentication [11], are the two authentication schemes proposed for the prevention of shoulder surfing attack. The user has a secret password and the ratings for the colors registered initially. Secret password play a role when authenticating via the pair based authentication whereas the color ratings play a role when authenticating via the hybrid textual scheme. The pair based mechanism displays the user a UI with a matrix which consists of 26 letters and 10 numbers. Hence, a total of 36 elements via a 6 x 6 matrix. The user needs to use his secret password to identify the session password from the matrix. Consider the secret password is "Password". So, to identify the session password, the user will need to take the first two characters of his secret password which is "Pa". Look for the"P" in the matrix and consider that as a row. The look for "a" and consider that as a column. The intersection of row and column will be the first character of the session password. Then again consider the next two characters of the secret passwords to identify the second character of the session password in the same way. Similarly, with respect to the hybrid textual scheme, while registering the color ratings, the user needs to specify a number for each color and remember the same. While authenticating, user will be displayed a row of 8 colors and a matrix again. Consider the first two colors and remember the ratings for them. The first one will act as row number and the second as column number of the given matrix. Get the number at the intersection and that will be the first character of your session password. Similarly, identify the other session password characters. This technique has a resistance to the shoulder surfing attack, brute force attack, random guessing attack and the dictionary attack too. These schemes are totally new to the users and needs to be tested thoroughly.

Collective Self Analysis:

All the schemes listed above has some benefits, and limitations too. Almost all of them show a potential to resist the shoulder surfing attack. Some are easy to use and some have a hectic and time consuming process of authentication. But, all target towards resisting the shoulder surfing attack and increase the security in our day to day online world. We will need to develop an authentication system that has a great balance between usability and the security. The key is to have a different password during the each login.

Key Motivation and Challenges:

Authenticating via entering a pin password is a common authentication technique these days. As the pin password's length is small, it is highly hack able via naked eye based shoulder surfing. This motivated us to research more on this topic. The challenging task here is to frame an authentication technique that is resistant to shoulder surfing attack. This technique will allow us to enter a password in public without compromising the password itself.

III. Proposed Methodology

A. Architecture

Fig.1.The user interface for theproposed mechanism.

Let's go through the proposed graphical PIN entry authentication system. We are using digits 0,1, ...,9 , like every other PIN based authentication systems. The length of the PIN password is 4 digits. Assumption is that one-time registration process for thisis carried out at a safe location, where no oneelse and no cameras are installed.

As shown in Fig. 1, the user interface of this proposed scheme contains of 4 rows with arrows on the left and right side of each row.

Each row consists of 10 columns. Each column will be populated with a random digit ranging from 0,1,...,9 in every session. The digits can be moved to the left or right side with the help of arrow buttons.

There is an "ENTER" button and the "RESET" button at the bottom. The "ENTER" button will be used to verify the graphically entered PIN once the user have selected the four digit PIN password by moving the digits using the left and right arrow keys. The "RESET" button will reset and randomize the rows any time in the whole session authentication process.

The registration phase is a two-step process. In the first step, the user will need to enter the four digit PIN code same as like any other traditional PIN based authentication scheme. In the second step, user will need to decide one secret location of his choice from the 40 available locations. The user can select a location by specifying the row and column numbers of the location in the row and column number's dropdown.

{0,0}	{0,1}	{0,2}	{0,3}	{0,4}	{0,5}	{0,6}	{0,7}	{0,8}	{0,9}
{1,0}	{1,1}	{1,2}	{1,3}	{1,4}	{1,5}	{1,6}	{1,7}	{1,8}	{1,9}
{2,0}	{2,1}	{2,2}	{2,3}	{2,4}	{2,5}	{2,6}	{2,7}	{2,8}	{1,9}
{3,0}	{3,1}	{3,2}	{3,3}	{3,4}	{3,5}	{3,6}	{3,7}	{3,8}	{3,9}

Fig.2. All possible locations with coordinates.

In Fig. 2, it is shown that one location is selected as a secret location, which is highlighted in red color. The coordinates of this location will be stored in the database, for example (2, 4) and the 4 digit pin will also be saved. The secret location plays a crucial role in the whole authentication and the user will have to remember it for getting authenticated.

Once the registration is done, the next important part is the authentication phase. The user will be displayed with the UI as shown in the fig. 1. In the first step, the user will have to note the digit seen at the secret location(selected by the user while the registration phase). The secret location is named as reference location and digit populated at this location is called as reference digit.

In the second step, the user will have to select the 4 digit PIN password through the following method. The first row will be forselection of the first digit of your pin code entered while registration. Likewise, the second, third and fourth rows will enable you to the select the second, third and fourth digits of the PIN code in turn.

For first digit selection, the user will need to move the digits from the first row using the arrows on the left and right side, until the first digit of the PIN comes to the location of reference digit. The same reference digit need to be considered for the second, third and fourth rows for the entering the second, third and fourth digits of the PIN code in turn. An example given below will help to understand this methodology better.

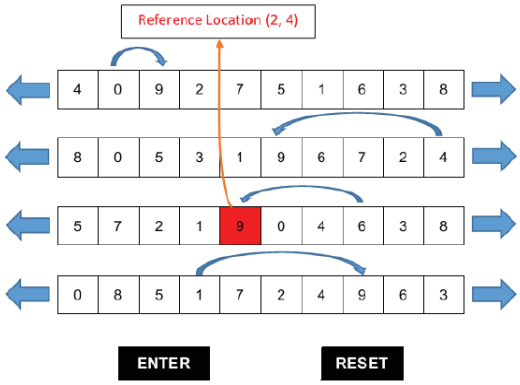

Fig.3.The state before all the pin numbers are entered.

Let us go through the proposed authentication scheme with an example. Imagine that at the time of registration,user selected the location (2, 4), for reference digit as shown in Fig. 3 and the four digit pin code is "0461". As seen in the Fig. 3, the reference digit for your current authentication session is "9" as it is present at your secret reference location (2,4). The first row in Fig. 3 will be used for entering the first digit of the PIN"0461". To select the first digit, "0" of the PIN code, you will need to move "0" to the location of reference digit, which is "9". In simple words, move "0" to the location of "9" in the first row using the arrow buttons of the first row.Now, the pin is entered in the first row. Let's enter the pin in the second row. So, the second digit of your pin is "0461" is 4. So, move "4" to the location of "9" in the second row using the arrow buttons of the second row. Now, the pin is entered in the second row.

Similarly, you need to move the third and the fourth digits of your PIN code at the location of reference digit in third and fourth rows respectively. Once all the digits of the PIN code are at the position of reference digit "9", as shown in Fig. 4, the pin selection process is complete, and now you can hit the "Enter" button. After you hit the "Enter" button, the system will check the entered pin code digits with respect to the reference digit. If all the four digits of your pin code are correctly placed in all four rows respectively, your session will be authenticated. Else, you will not be authenticated and the access will be denied, and you will have to go through the entire authentication process once again. Please note that the secret location is always fixed, but the digit present at that location will vary during each session because every time we go through the authentication process, a random number will be placed at that location.

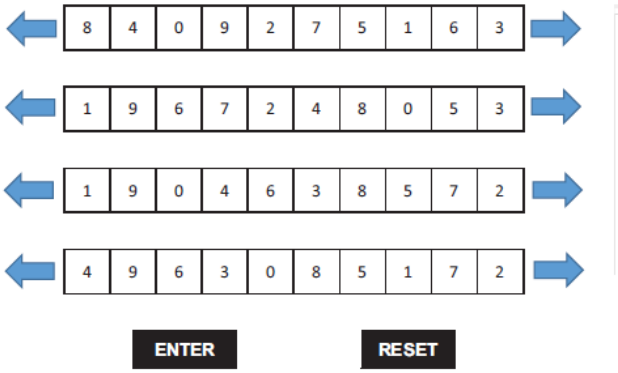

Fig.4. The state after all the pin numbers are entered

Below is the pseudo code algorithm for the graphical pin entry mechanism.

B. Algorithm 1 (Graphical Pin Entry)

Below are the inputs needed for this algorithm

Input:
D datatable,
G gridview,
R registered user pin fromdb,
U user input

Below is the output of the algorithm.

Output:
Authentication status

Pseudocode:
Get the value V at thereference location S from datatableD

FOR EACH row in data table D do
Find value V and log the row/col co-ordinates in expected location list L
END FOR

Get the values from gridview G at location L and log them in list P

```
FOR EACH item in list P do
   IF (R(i) == P(i))
Add true in FinalCheckList F
   ELSE
Add False in FinalCheckList F
   END IF
END FOR

IF (all items inFinalCheckList F == True)
Status = Authentication successful
ELSE
Status = Authentication failed
END IF
```

IV. Security Analysis

A. Naked Eye Based Shoulder Surfing Attack-

We have directed an experiment to access resistance of our proposed scheme against human or naked eye based shoulder surfing attack. We have appointed four university student with information security background and age limit between 21 to 33 years. Before starting the experiment, the members were given enough time to understand the working of the model of our scheme. Each participant successfully created his login credentials using our model and then used these credentials to login multiple times. Members were not allowed to interact with each other during the practice session. Throughout the experiment, every participant has to enter his login credentials, and the remaining two has to speculate the PIN code by watching the screen with clear line of sight. We have provided each participant with a paper and pencil to write down the guessed PIN code. After this experiment, we have 6 PIN codes guessed by 3 different participants. But nobody can guess a right 4 digit PIN code.

B. Random Guessing Attack-

In random guessing attack, the adversary doesn't have any information about the PIN code or reference location. Therefore the attacker will try every possible four digit PIN code against every possible reference digit. By closely following the PIN code selection process, we can find out that for every single random guessing authentication attempt we have got 10 PIN codes, each of the PIN code is corresponding to each reference digit from 0 to 9. In other words, we can say that if we randomly guess 10,000 PIN codes against one of the reference digits, indirectly we are guessing 10,000 PIN codes against each of the remaining 9 possible reference digits. Therefore the probability of random guessing attack in our proposed scheme will be as mentioned in (1).

$$P_{RGA} = \frac{1}{10{,}000} \quad \text{.....} \quad (1)$$

C. Recording Based Shoulder Surfing Attack

In the case of video based shoulder surfing attack, we have presumed that the attacker has only one video recording of a successful authentication process. The attacker doesn't have information about the reference location or reference digit. But he knows that there could be ten possible reference digits from 0 to 9. Therefore by following the recording, he can find out ten possible PIN codes. One against each reference digit from 0 to 9. We can write these ten possible PIN codes as a set P0, P1,P2,....,P9 . Among these ten possible PIN codes, one is correct. Thus, the probability of guessing the PIN code through a single recording is 10% as shown in (2).

$$P_{RA} = \frac{1}{10} \quad \text{.....} \quad (2)$$

V. Result And discussions

In this section, we analyzed our proposed authentication system to check the level of usability by taking into account the time taken by the users to login and also the failure rate via a user study. Please refer below, the details of our tests:

Fig.5. Our proposed system UI implemented in C#

A. Preparations

We designed the prototype of our proposed authentication scheme as an ASP.Net application using C# language. Please refer the above Fig. 5 for the user interface of our prototype.

B. Participants

We asked 20 users to participate in this user study who were between the age limit from 22 to 35 years. Out of these, sixteen users were male and the rest four were female. All of them were at ease with the use of smart phones as also the old-fashioned PIN based authentication mechanism.

C. Procedure

Our experiment was divided into two sessions. We kept an interval of 2 days between both the sessions. During the first session, we demoed the actual working of our project by a simple walkthrough of our whole authentication from registration to login. Once this was done, we asked all the users to register themselves by providing the required information like the username, the secret four digit pin code, the reference location. All of them tried logging in multiple times with their credentials. The session concluded after everyone confirmed that they were fully aware of the working of our proposed authentication technique after many successful login attempts.

In the second session, everyone were asked to login using their registered credentials. Everyone needed to successfully login for the five times. Time and number of tries weren't limited. We tracked the total number of failure attempts and concluded the calculation of error rate.

The usability was calculated on the basis of login time and error rate. Table I shows the login times. We took the maximum and minimum login times of each user and then calculated the mean, median and the standard deviation. From this, we derived that the average minimum time for login as 21 seconds.

Table I: Mean, Median and the Standard Deviation for maximum and minimum time required to login into our proposed scheme for 20 users.

Maximum Time in Seconds			**Minimum Time in Seconds**		
Mean	*Median*	*Standard Deviation*	*Mean*	*Median*	*Standard Deviation*
30.45	30	7.06	21.5	21	7.16

Table II shows the failed login attempts. Hence, error rate is approximately.8% and the success rate is approximately. 92%.

Table II: Failed Attempts until all the users logged in successfully for the 5 times.

Failed Attempts	0	1	2	3
Users	12	6	1	1

While performing a random guessing attack, the opponent does not have any data regarding the PIN code and the secret location. Hence, the enemy will try every possible four digit PIN code for every possible reference digit. By analyzing the PIN code selection process, we can say that for every single random guessing attempt, we have got 10 PIN codes and each of the PIN code is corresponding to each reference digit from 0 to 9. So, we can say that if a person isguessing randomly 10,000 PIN codes against one of the reference digits. Indirectly, we are guessing 10,000 PIN codes against each of the remaining nine possible reference digits. Hence, the probability of random guessing attack in this scheme will be as mentioned in (1).

VI. Conclusions

With this paper, we have designed a graphical PIN based session authentication system that is capable to resist against the shoulder surfing attack. The graphical pin entry mechanism for authentication is very strong against the shoulder surfing attack. It is capable of resisting the recording based shoulder surfing attack, assuming that the hacker has only one video recording of a successful session authentication. To achieve this, the mechanism uses a specific user interface which facilitates indirect pin entry, graphically. With respect to the security, after analysis, it shows that this mechanism offer resistance not only against human shoulder surfing attack but also against recording based shoulder surfing attack and that too without compromising the security against random guessing attack. The graphical pin entry mechanism provides a great balance between security, usability and the feasibility.

The limitation is only that the registration should be done in a safe and secure environment. There should be no recording devices like camera present. As an added security, the database that will store the PIN and the secret location co-ordinates will need to be encrypted so that if in case the database is hacked, the hacker should not be able to get any meaningful data.

After the experiment that we conducted with 20 participants, we found that the average login time is 21 seconds and the error rate is approx. 8% and the success rate is approx. 92%.

We hope this study be useful for those who have new ideas on secure and useable graphical authentication system.

As a future scope, the graphical pin entry mechanism can be combined with any other existing authentication mechanisms as an added layer of security.

Applicability

Providing an extra layer of security to any application, generally sensitive applicationslikebanking and financial domain where the security is the topmost priority.

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