

## Prevention or Identification of Web Intrusion via Human Computer Interaction Behaviour – A Proposal

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### ABSTRACT

*The present work proposes a new technique for the identification or prevention of intrusion in web applications via the monitoring of the user interaction behaviour. We report preliminary results in a verification task based on a user claiming his identity and being accepted or detected as an intruder after some time of user interaction monitoring. We describe the acquisition system that enables the remote monitoring of the user human computer interaction and the recognition system that detects an intrusion in the system, and present some preliminary results.*

### 1.0 INTRODUCTION

Malicious intrusion in Internet sites either with the intention of disrupting the system or to steal information can threaten the normal operation of the Web. We propose a new biometric technique capable of monitoring the user behaviour in a web site in order to prevent or detect intrusion by validating the user identity claim, normally made in a logon page. The system is based on the learnt human computer interaction behaviour of the genuine users.

We developed an acquisition system, called Web Interaction Display and Monitoring (WIDAM) [3], that collects the user interaction data by recording the mouse movements, clicks and key presses, among other interaction events, while the user is browsing a web page.

The biometric system uses this last system to verify the identity of a, while he is navigating in the web page. The classification is based on statistical pattern recognition models, and is done after a period of interaction. This period can be selected in order to define the security level of the biometric system. In our preliminary results we obtained a level of security similar to other behavioural biometrics techniques if a period of 60 seconds of interaction is collected. This methodology introduces a possibility of applying an biometric layer to web systems with the present technology. We will now introduce some terminology used in the biometric area.

Biometric systems can be divided in two types [7]: (1) Identity verification (or authentication) occurs when a user claims who he is and the system accepts (or declines) his claim; (2) Identity identification (sometimes called search) occurs when the system establishes a subject identity (or fails to do it) without any prior claim. Biometric techniques can also be classified according to the type of characteristics explored : (1) physiological --- a physiological trait tends to be a stable physical characteristic, such as

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finger print, hand silhouette, blood vessel pattern in the hand, face or back of the eye. (2) behavioural --- a behavioural characteristic is a reflection of an individual's psychology.

The evaluation of a biometric technique requires the definition of metrics that can be used for the comparison of performance among different techniques [8], typically: False rejection rate (FRR) --- rate of accesses where a legitimate user is rejected by the system; False acceptance rate --- rate of accesses where an intruder is accepted by the system; Equal error rate (EER) --- the value at which FAR and FRR are equal.

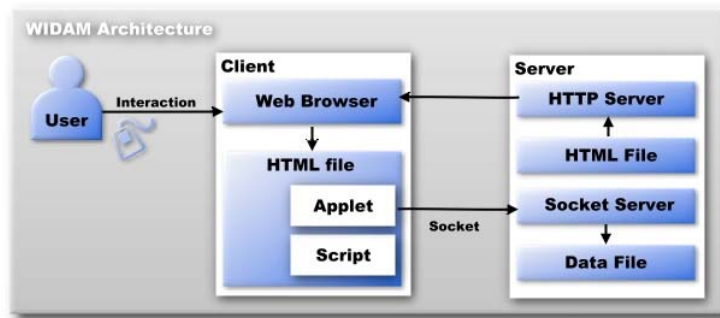


Figure 1 The WIDAM Architecture

In this paper we propose both a web based user interaction monitoring system called Web Interaction Display and Monitoring, WIDAM, and a new behavioural biometric technique based on web interaction via a pointing device, typically a mouse pointer. The normal interaction through this device is analysed for extraction of behavioural information in order to link an identification claim to an individual.

In the following section we present the user interaction acquisition system, WIDAM. In section 3 we describe the authentication system, focusing on the sequential classifier. Section 4 presents experimental results obtained using the collected data. Conclusions are presented in section 5.

## 2.0 THE ACQUISITION SYSTEM

The acquisition system, WIDAM, (this system is presented with more detail in [3]) enables the user interaction monitoring, analysis and display on web pages. The system can be called as a remote display system that enables the synchronous and asynchronous observation of the user interaction.

WIDAM allows the usage of an interaction recording system directly over a web page, based on the Document Object Model [5] (DOM) of the web page. The system works in a normal web browser with java and JavaScript capabilities, without the need of any software installation. WIDAM is a lightweight networked application using low bandwidth comparatively to image based remote display systems. The WIDAM Architecture is composed by a client and server applications, as depicted in figure 1. The user accesses the monitored WIDAM web page via a web browser that connects to the server. Then, the server sends back to the user a web page that is capable of monitoring and displaying the user interaction. This page creates a connection to the server and selects one of the services provided by WIDAM. Then the client and the server exchange messages using a specific protocol.

The client works in any web browser capable of executing JavaScript code and Java Applets, independent of the operating system. When the users enter into a page of the WIDAM system, an applet is launched. This applet creates a socket connection that enables the message passing from, and to the server. The client loads the html page and sends an handshaking message through the open socket, specifying which type of service is requested.

In the case of a Recording Service or Synchronous Monitoring Service, the script sends a request to the browser, asking for notification of the user interface events (a sub set of the events from the Document Object Model Events [9] listed in table 1).

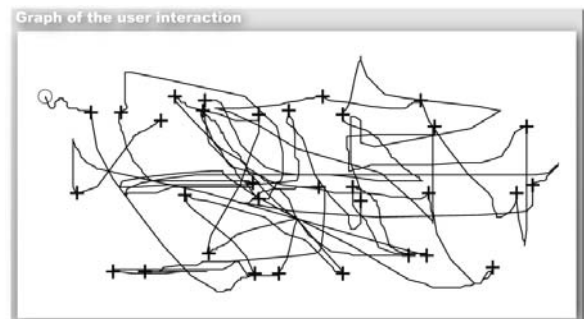
ID	Event handler	Event cause
0	onMouseMove	The user moves the cursor.
1	onMouseDown	The user presses a mouse button.
2	onKeyPress	The user presses a key.
3	onUnload	The user exits a document.
4	onMove	The window is moved.
5	onSelect	The user selects some text.
6	onResize	The window is resized.
7	onBlur	The window loses focus.
8	onFocus	The window receives focus.

**Table 1 DOM events captured by WIDAM**

For the purpose of the intrusion detection technique being developed, the WIDAM system operated in a recording mode, over a web page with the memory game: a grid of tiles, each tile having associated a hidden pattern, which is shown for a brief period of time upon clicking on it; the purpose of the game is to identify the matching tiles. The WIDAM system presents a web page to the user, asking for his identification (name, and a personal number). Then the system presents an *interaction acquisition page* with the memory game (that could be any html web page), depicted in figure 2. This page is monitored by the WIDAM application that records all the user interaction in a file stored in the web server. Figure 3 shows a graph of a user interaction while playing an entire memory game. The graph is produced by joining every sequential mouse movement with lines and using a cross mark to indicate a mouse click.



**Figure 2 Interaction test page: the memory game.**



**Figure 3 Graph of the user interaction in the game.**

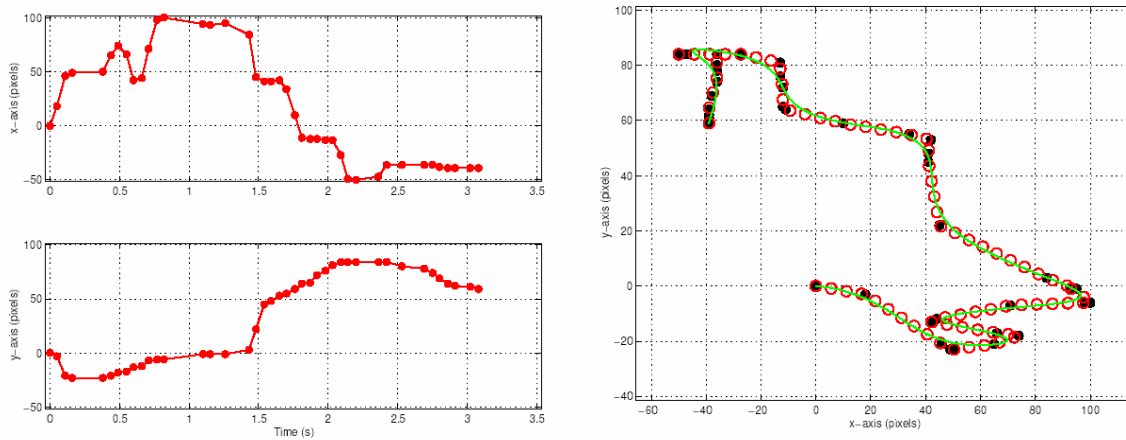
### 3.0 THE AUTHENTICATION SYSTEM

An experimental system - the authentication system - was developed to verify the possibility of detecting an intrusion or invalid identity claim, using the computer interaction information, specifically based on mouse movements performed between successive clicks, which we will call a *stroke* (see figure 4).

Figure 5 presents the acquisition and recognition systems and its respective building blocks. The acquisition system was addressed in the previous section. The recognition system comprises the following modules: (a) feature extraction; (b) feature selection; (c) parametrical learning; (d) statistical sequential classifier. The recognition system reads the interaction data from the stored data files produced by the acquisition system. The interaction data passes a feature extraction procedure, creating a 63-dimensional

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vector, exploring both spatial (related to angle and curvature) and temporal (related to duration, position, velocity and acceleration) characteristics of the strokes. More details can be found in [4].



**Figure 4** Left: Input signals generated by the mouse move events. Right: The x-y representation of the signals. Black circles represent the input sampled points generated by mouse move events. White circles represent linearly (equidistant) interpolated points. The line represent the smoothed spline interpolation.)

The system has an enrolment phase, where the global set of extracted features are used in an algorithm that selects a set of “best” features for each user, using the equal error rate as performance measure (feature selection block in figure 5), using the Sequential Forward Selection (SFS) [6] that selects the best single feature and then adds one feature at a time to a vector of previously selected features. The algorithm stops when the equal error rate does not decrease.

The classification rule assumes a statistical model for the feature vectors. The learning phase consists of the estimation of the probability density functions,  $p(X)$  (where  $X$  is the feature vector of a stroke), from each user's data. Considering that each user constitutes a recognition class, and assuming statistical independence between features,  $p(X)$  factorizes into  $p(X|user) = \prod p(x_i|user)$ . We use as a parametrical model for  $p(x_i|user)$  the *weibull* [1] distribution ( $p(x|a,b) = a b x^{(b-1)} e^{(-a x^b)}$ ). Given the data from one user and one feature, maximum likelihood estimates of the parameters  $a$  and  $b$  are obtained.

The classifier's purpose is to decide if a user is whom he claims to be, based on the patterns of interaction with the computer. We consider that the  $i^{th}$  user is denoted by the class  $w_i$ ,  $i=1, \dots, L$ , and  $L$  is the number of classes. As defined before, a feature vector is associated with one stroke. Given a sequence of  $n_s$  consecutive strokes executed by the user,  $w_i$ , interaction information is summarized in the vector  $\mathbf{X} = X^1 \dots X^n$ , consisting of the concatenation of the feature vectors associated with each stroke.

The classifier will decide to accept or reject the claimed identity based on two distributions: the genuine distribution  $p(X|w_i)$ , and the impostor distribution  $p(X|w_j)$   $j \neq i$  that is based on a mixture of distributions (weibull distributions), one for each other user not equal to  $i$ , weighted by  $L$ , the number of users.

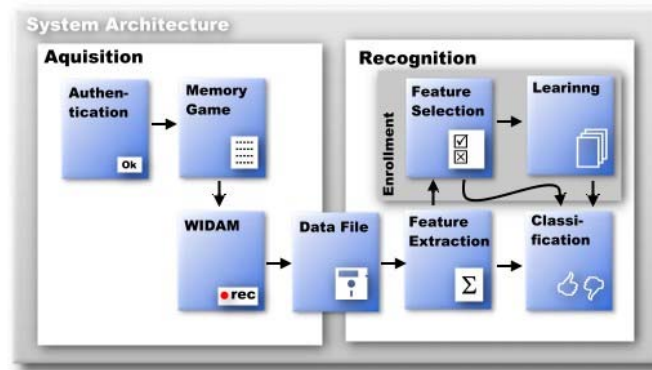


Figure 5 Authentication system architecture.

Since  $p(w_i|X)$  represents an estimate of the probability of the classification being correct, we establish a *limit*,  $\lambda$  to select one of the decisions, using the decision rule:

$$Accept(\mathbf{X} \in w_i) = \begin{cases} true & \text{if } p(w_i|\mathbf{X}) > \lambda \\ false & \text{otherwise} \end{cases}$$

To present result about the classifier performance we adjust  $\lambda$  to operate in the equal error rate point, establishing the error of detection of intrusion equal to the error of accepting an intrusion.

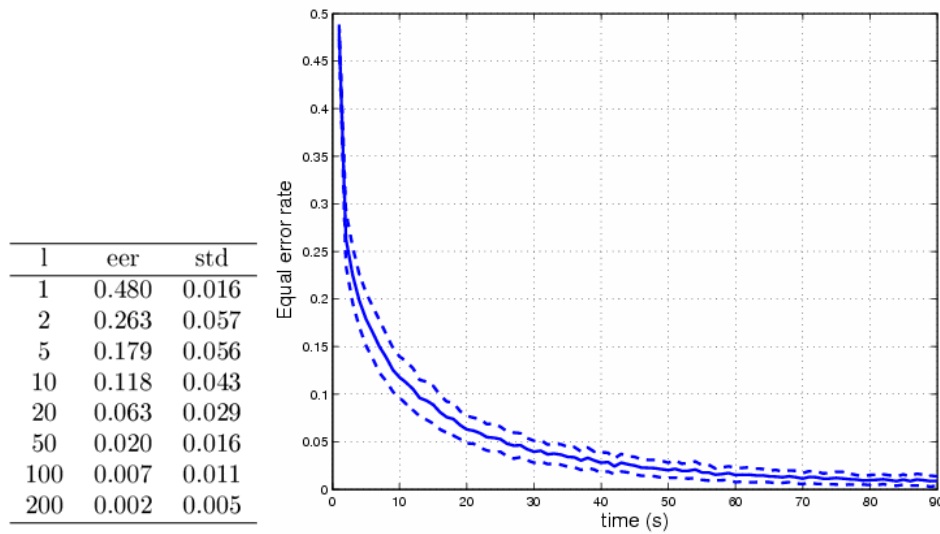
#### 4.0 RESULTS

We asked 50 volunteers (engineering students) to use the developed system, playing several memory games during about 10-15 minutes. This way, we created an interaction repository of approximately 10 hours of interaction, providing more than 400 strokes per user. The acquisition system monitors the pointing device with a sample rate of 50 times per second, producing messages from the client to the server that require approximately 1 Kbytes/s (950 bytes per second) as the maximum bandwidth. For instance, the ten hours of interaction occupies 36 Mbytes of disk space.

In order to use the same number of strokes per user in the tests performed, we randomly selected 180 strokes from each user. The set of strokes was divided into two equal parts, one for the training phase and other for the testing phase. Using the training set we learnt the parametrical distribution  $p(x_i|user)$  for each user and each feature. Feature selection used the same data set and was tuned for each user, based on the performance of the system using sequences of 10 strokes. When testing the system for one user, we consider an intruder as one of the other users. The test function returns the equal error rate given  $N$  sequences of strokes of length  $l$  using the classifier tuned for user  $i$ . The input sequence of strokes of a test is composed of  $N/2$  strokes randomly sampled from the testing set of the user, and  $N/2$  strokes randomly sampled from the testing sets of all the other users.

One of the free variables of the system is the number of strokes that the system will use in the verification task. Bootstrap [2] estimates of the system performance as a function of the sequence stroke length (from 1 to 100 strokes) was obtained using 10000 bootstrap samples from the test set. The mean duration of a stroke is approximately 1 second. A graphical display of these results is shown in figure 6. As shown, the mean value and the standard deviation of the EER progressively tends to zero as more strokes are added to the decision rule. This illustrates the refinement of the performance obtained by the sequential classifier.

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**Figure 6 Equal error rate results of the verification system. The solid line is the mean of the equal error rate of all users. The dashed lines are the mean plus and minus half standard deviation**

Table 2 presents EER values reported in the literature for several biometric techniques [10]. Preliminary results show that the proposed technique, based on behavioural information extracted from the interaction with the computer, can achieve comparable performances with other biometric techniques.

Biometric technic	Equal error rate
Retinal Scan	1:10 000 000
Iris Scan	1:131 000
Fingerprints	1:500
Hand Geometry	1:500
Signature Dynamics	1:50
Voice Dynamics	1:50
30s of User Interaction	1:50
60s of User Interaction	1:100
90s of User Interaction	1:200

**Table 2 Comparison between several biometric techniques**

## 5.0 CONCLUSION

The human computer interaction behaviour used in this work carries information related to the author identity. We have studied this source of information in order to develop a system capable of detection or prevention of web intrusion by the means of a behavioural biometric layer in web applications.

The acquisition of the interaction was based on the developed WIDAM system that works over the World Wide Web collecting the mouse clicks and movements among other interaction events.

The intrusion detection is based on a new biometric technique based on statistical pattern recognition methods. The biometric layer rejects the user claim past entering in the system by logging thru the security page of the web application. After an established period, the claim is validated or rejected via the recognition system that compares the acquired user interaction with the features of the previously acquired data from the user.

The prevention of intrusion in web sites is accomplished by the immediate rejection of automatic scripts that try to gain access, commonly called bots. The bots do not present the typical human computer interaction, since the scripts interact directly with the server without any usage of interaction devices. This absence of events from a typical human can easily be used to deny access to any automatic malicious (or not) script.

The results of the tests with 50 users and a total of 10 hours of interaction showed that this technique can be applied to produce a web based behavioural biometric system to identify and prevent intrusion in web applications. The performance results are comparable to some of the behavioural biometric techniques an inexpensive technique that operates remotely using the human-computer interaction behaviour.

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