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# COMMUNICATION IN WEB-BASED LEARNING ENVIRONMENTS: FOR BETTER COLLECTING AND EXPLOITING LEARNERS' TRACKING DATA

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## ABSTRACT

It is obvious that the tracking data acquired from each learning environment has become more advantageous to various participants in the learning process. As an example, the tracking data of learner's activities are used to depict not only the activities themselves but also the outputs of the activities that learners carried through. Tracking data are somehow considered useful elements, exploited by researchers and developers to improve learning environments as well as to develop other educational tools and applications. As yet, their riches and complexities have brought up a number of new research challenges, among which the use of the tracking data for assisting the participants in the learning process, both learners and instructors. In this paper, we present an approach for better collecting and exploiting the tracking data of the learner's activities while interacting with Computer Mediated Communication tools in Web-based learning environments.

## KEYWORDS

E-Learning, Human Computer Interaction, tracking data, tracking system, discussion forum

## 1. INTRODUCTION

Providing more convenient supports to the participants in the learning process has become one of the research interests in the field of Web-based environments for human learning. Meanwhile, the need of efficient educational platforms, tools, applications, etc., has been steadily increasing. As it is obvious that in distance learning situations, the instructors are strongly interested in being aware of the learners' activities and being able to monitor effectively the learning sessions, while the learners request for extra facilities for their communications between them and the instructors. In compliance with such growing demands, we have conducted a research project, which is particularly involved in keeping track of the learner's activities through the distance learning platforms and exploiting the tracking data in different learning contexts.

Tracking data are too called "traces", generally generated by tracking system in accordance with its defined trace format or model (Choquet & Iksal, 2007). The collected traces are used to depict the activities of the users and/or the events occurred during the use of the systems in a specific context. As yet, the traces and their complexities have brought up a number of new research challenges, like building intelligent tracking systems to collect the tracking data in the assorted computer-based learning environments, using automatic traces analysis methods and providing the accurate synthetic information to the users, etc...

In Web-based learning situations, the trace of learners' activities is a significant source of information that reveals not only the activities themselves, but also their outputs (the results of the activities that the learners carried through the learning process). Therefore, traces are known as important elements, keeping the instructors informed of different learning aspects of learners, like the progress of the learners' activities (Després, 2003) and the exchanged communications between learners (Komis *et al.*,2002). This allows the instructors to supervise each individual as well as groups of learners while being in remote situations. Furthermore, by analyzing the traces in collaborative learning environments, the instructors could evaluate

social and cognitive aspects of learners (Riccardo & Dimitrova, 2003). The synthetic information derived from the trace analysis could help learners review their own behavioral aspects and that of others (Donath *et al.*, 1999). Last but not least, tracking data plays another role in helping both researchers and developers improve the learning platforms and develop adaptable educational tools that match better the necessity of each user (Avouris *et al.*, 2003).

This paper presents an approach for efficiently tracking the learner's communication activities on Computer Mediated Communication (CMC) tools. We begin section 2 by uncovering the principal research issues in tracking user's activity and exploiting the tracking data in Web-based learning environments. In section 3, we present the different levels of Human and Machine Interactions to be observed and the generation of the tracking data that correlate to each level of interactions. We give a concrete example of our Web-based tracking system in section 4. The example shows how a user's communication activities in discussion forums are being captured and how tracking data are being interpreted.

## 2. LEARNERS' TRACKING DATA IN WEB-BASED COMMUNICATIONS

CMC tools have been widely employed in all platforms of distance learning as important means for communications between learners, and between learners and teachers. Assisting the participants in the learning process during and after their communications and providing them more useful information on their activities are our research interests. A number of key issues related to the use of CMC tracking data have been discussed in May *et al.*, 2006. In this section, we would like address other important research challenges in Web-based education areas, particularly keeping track of learner's communication activities on CMC tools.

### 2.1 Collecting learner's tracking data

In order to track efficiently the learners' communication activities on CMC tools, the tracking system must observe closely where the activities are going to be carried on. However, most systems were designed to observe user's activity only on the server side, the user's interaction on the client side is completely ignored. In this case, the granularity of traces should be rather large and the information returned from the trace analysis might not be accurate enough to reflect the complete activities of users during their communications. In our research work, the observation of users' activities is done on both client and server side, which means keeping track of (i) Human-Computer Interactions, (ii) Computer-Mediated Human Interactions (either Human-Human Interactions Mediated by Computer), and (iii) Computer-Computer Interactions. This allows us to have different compositions of traces with finer granularity. This approach will be discussed in detail in section 3.

Another remark we made about the existing tracking systems is that the activities of lurkers on CMC tools have never been tracked down. Even lurkers are sort of users who do not participate in the communications between other users and who are not "visible" to other users when online, they are recognized as an important part of Internet community, as mentioned in (Smith, 1999). Hence tracking the lurkers' activities and analyzing their traces permit us to understand more about the lurker behavior and their influence in distance learning environments (Takahashi *et al.*, 2003). This is one of the particularities of our research, tracking every other user and studying their traces by hoping to address more convenient supports to CMC-tool users, especially the teachers so that they can be more aware of other user's activities, including lurkers'.

### 2.2 Storing tracking data

Since each choice of modeling and structuring traces was made just to match each individual need, traces of user's activities stored on existing CMC tools are often carried out in an ad-hoc manner, which either confines the reusability of data in different purposes or makes data exploitation difficult (i.e. traces can be hard exploited independently by different exploitation tools).

During the study of related works, we notice that most tracking systems still use text log files to keep track of users' communications on CMC tools. Consequently, the traces stored in log files have been rarely exploited by the users (instructors and learners) either because of the ignorance of their existence, or because

the traces do not match the exigency of the users. Besides, the structure of traces in a log file varies from one CMC tool to another, due to the fact that each log file depends on how it was generated. Yet, there is a lack of semantic aspects for traces stored in log files (i.e. pure text log file).

To avoid this kind of situation, traces should be represented in a generic format, from which another standard or specific format can be created to represent the identical trace. In addition, it is needful to consider the possibilities to enrich the recorded traces: the fact that traces are being modified by adding more descriptive data (supplementary information) to its original representation, allowing traces to be restructured, transformed into another format, and reusable for other types of CMC traces exploitation tool.

### 2.3 Exploiting learner's tracking data

The learner's tracking data are somehow made up of specific information which is not directly interpretable by the CMC-tool users without the assistance of the specific tools. The traces can be analyzed quantitatively and/or qualitatively with both interactions analysis methods (Pozzi *et al.*, 2007) and content analysis methods (De Wever *et al.*, 2006). The major problems that we usually encounter are due to the effectiveness of the used method and the quality of the results returned from the traces analysis. As matter of fact, the analysis can not be done efficiently when the recorded traces are not descriptive enough and when there is lack of traces indicators. Thus, the root of the problem seems to be much more correlated to the collection of the tracking data. Once again, the approach described in section 3 shows how to efficiently track learners' communication activities. Regarding the traces visualization, in order to facilitate users, the visualization tools must enable users to easily interrogate the trace repository by simple formal query and transform traces into graphical representations. Moreover the visualization tools should not only provide the overview of users' activities, but allow users to visualize, as rigorously as possible, the traces of users' activities and the same traces in different visual representations as well as in different scales.

## 3. PROPOSED APPROACH FOR EFFICIENTLY TRACKING CMC ACTIVITIES

By studying a number of diverse methodologies and techniques for Human-Computer Interaction design we were able to give a closer look at the possible ways to track efficiently the user's communication activities on Computer Mediated Communication tool. In order to help the conception of our approach, we have adopted the 5W1H method (When, Where, Who, What, Why, and How). Here is an example of how the approach was built: we started by questioning the *who* and *why* questions to identify the real need of different participants in the learning process and to contextualize the CMC activities to be tracked. This has been done through the participation of researchers and PhD students who are working in different research disciplines. It is important to mention here that every answer to the questions was useful for us to determine the objectives of the research as well as the tasks to be accomplished by the approach. The nature of the tracking data as well as the use of the collected data were also clearly defined to make sure that the approach could satisfy as many as possible the requirements of the target users (i.e. teachers and students).

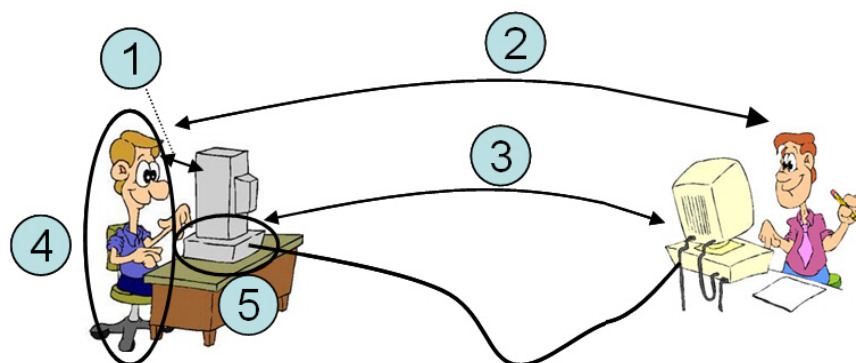


Figure 1. Different levels of Human and Computer Interactions to be observed

The other answers to the questions of *Where*, *What*, *When* and *How* to track learner's communication activities, gave us a clear view of what the Human-Computer Interactions are to be observed and how. We give below a presentation of the approach in a general context. An example with the collected tracking data of communication activities in a discussion forum will be presented in section 4.

### 3.1 Different levels of Human and Computer Interactions to be observed

As shown in figure 1, within a Computer Mediated Communication activity, five levels of Human and Computer Interactions can be observed:

**(1) The Human-Computer Interactions** refer to the user's actions while using the Graphic User Interface of CMC tools. Let us give an example of an activity "Writing a new message". The interaction between user and a CMC-tool interface can be "edit" message title or message content, "move" vertical scrollbars upward or downward, "drag & drop" smiles into the message, etc. All of these actions occurred only on his/her user interface, more precisely on the user browser without sending any request query to the server or to any other user's machine. In our study, we define the traces of user's activities by a composition of two parts of the traces: a part that represents activities on the server side, which is collected at the moment of exchanging user queries between client browser and server, and another part that represents the Human-Computer interactions on the client side (e.g. user Web browser).

**(2) The Human-Human Interactions Mediated by Computer** refer to the content of the interaction exchanged between users. With the same example of "Writing a new message"; all the written text on user interface will be submitted to the server or directly to other user's machine so that the message can be read by other users. To do so, user has to click on "Send" or "Submit" button. The message is being sent via a request query to the server or to the machine where the message must be stored or displayed. Tracking the content of the communication makes the tracking data more descriptive, with what we are able to know how a user writes a new message and what is written. Exploiting the tracking data at this level leads us to easily reproduce not only the general context of the communication activity that describes the successive sequence of user's interactions, but also the content of the communication.

**(3) The Computer-Computer Interactions:** keeping track meaningful events means to track also the computer input and output processes while a communication happens. The tracking data of Computer-Computer interactions serve two main purposes: (i) evaluation of the quality of the computer processes in exchanging the communication data and (ii) monitoring the CMC-tool performance. The results are most of the time very useful for the developers who seek to improve the CMC tools, and the researchers who are involved in development experiences. As an example, we commonly use the tracking data at this level, to debug our system and to strengthen the security of the communication.

**(4) The user behavior/attitude** while using CMC tool is a non-mediated interaction. It means every other actions of the user outside the computer environment (i.e. a user makes a phone call during the learning session). In some circumstances, particularly in distance learning situations, it is not sufficient to track only the computer mediated activity of the learners. Video and audio recorders are more practical in observing the learner behavior. The audio-visual data can be then used for multipurpose, among which the analysis of user's behavior while working individually or collaboratively.

**(5) The computer action without user action:** there are plenty of computer actions that occur automatically without any user action. As an example, a pop-up message telling the user that his/her session in the chat room will be expired in 5 minutes, or a jingle to alert that a new member has logged in to the forum etc. Tracking such interaction can be done on both client and server side. On the client side, we can capture most of events that occurred and showed up on the user interface, as on the server side, the events will be captured once the request query has been lunched and executed.

### 3.2 Use model for the observation

Since there is a variety of CMC tools used in Web-based learning environments, the wise solution is not to build for every single tool a tracking system. The key to the solution is to study the common points and the particularities of each tool and to propose tracking system architecture, which is applicable in different CMC tools.

Here is an example; it is undeniable that every CMC tool provides a functional tool for “*writing a message*” and that is the common point. The dissimilarity is the possible ways a user can employ it to write a message. The particularities of CMC tools are mainly about the user interfaces and the types of Human and Computer interactions available in each tool: when a user writes a message in *forum 1*, placing his/her message in to a thread category is feasible through a multi-selected drop list. The user would do that otherwise in *forum 2*, because instead of multi-selected drop list, *forum 2* proposes a set of checkboxes for the thread categories. The final results of that activity are the same but the way the user interacts with the two forums is different. Thence, we started to formalize the **use models** to describe the way users employ each functional tool to perform their communication activities. A use model enables us to (i) define the context of user’s activities and (ii) identify every **user action** on the **interaction object** and its associated **events**. As shown in figure 2, a use model for an activity called «*Post a new message*» on the forum. The interaction objects in the context of this activity could be a «*Post new*» button, a «*Form for a new message*», and a «*Submit*» button, by which users employ to post a new message.

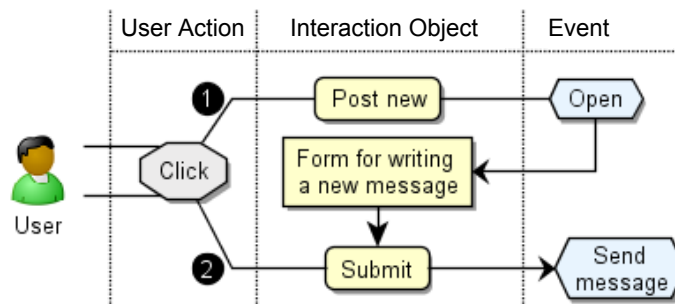


Figure 2. An example of a use model for an activity «*Post a new message*» in a discussion forum

The arrow (1) represents a sequence of event that happened when the user clicks on the «*Post new*» button to open the «*Form for a new message*» in order to write a new message. This form includes several other interaction objects, in this example, a «*Submit*» button. When the user clicks on the «*Submit*» button (arrow 2), there is another event called «*Send message*», representing the action that the user's message is being submitted to the server. The identification of the interaction objects and the successive events to be observed let the tracking system take into account every user's interactions with those objects, and to produce simultaneously the tracking system data of user's activities in accordance with its defined use model. In this way, each use model indicates **how** to observe, **when** to capture the user's actions and/or User-Machine interactions, and **what** to generate as tracking data.

## 4. CASE STUDY: TRACKING AND ANALYZING LEARNER'S ACTIVITIES ON DISCUSSION FORUMS

### 4.1 A Web-based tracking system for discussion forums

We presented in detail in (May *et al.*, 2007), the architecture of our tracking system for discussion forum and how each system component was built. We give below a brief description of the observation components of the tracking system.

The **observation components** were specifically designed with a number of **traces collectors**, which take care of observing user's interaction on client side (Human-Computer Interaction) and user's communications on server side (Human-Human Interactions Mediated by Computer). The observation component is attached with a use model, which describes how a communication activity on the forum can be performed by a user and how the trace collector generates instantaneously the tracking data to describe the interaction of users and its associated communication content.

Via figure 3, let us give an example of a tracking process, showing how an activity «*Post a new message*» is being tracked and how the tracking data are being generated and stored. The user's interactions on their browser interface, such as typing a message, drag & drop smiles into the message, moving scrollbar upward or downward, etc., will be captured by traces collectors on client side. The tracking data will be generated and temporarily stored on user's workstation. When the user clicks on the «Submit» button, there is a HTTP server request query to submit the written message to the server. The trace collectors on the server side capture that request query and generate simultaneously the tracking data to represent the communication activity (i.e. *post a new message*) as well as the content of the communication (i.e. *written message*). At each HTTP request, the temporary tracking data, previously stored on client workstation, will be submitted to the server. These data will be next synchronized with those on the server, structured and stored in the trace repository.

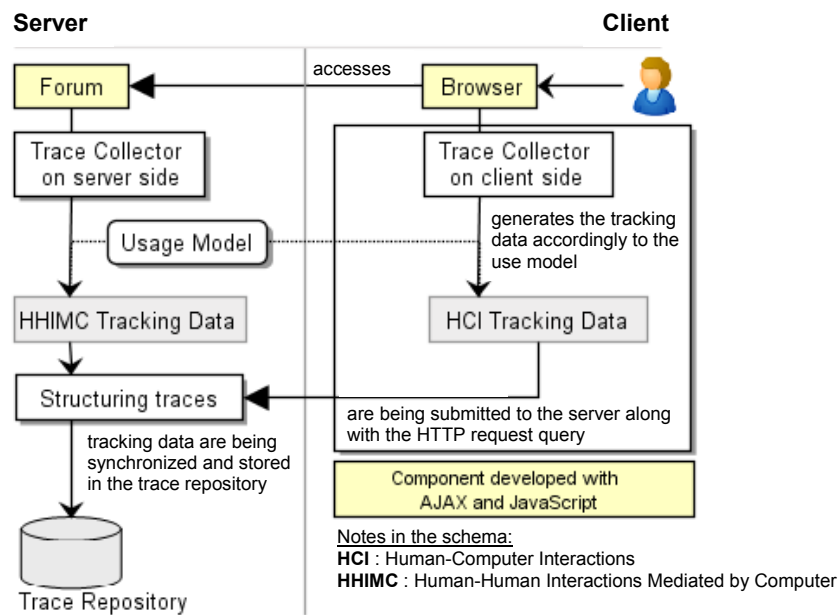


Figure 3. General architecture of Web-based tracking system on client and server side

We had developed the trace collector on the client side by using JavaScript language and AJAX technologies. JavaScript is a lightweight scripting language which is executed on user's Web browser (client side) and supported by any kind of Web browser. AJAX (Asynchronous JavaScript And XML) is a cross-platform technique usable on many different operating systems and Web navigator as it is based on open standards such as JavaScript and XML. With AJAX, we were able to make our Web-based tracking system more flexible in term of manipulating the tracking data directly at the client side, such as generating and sending the tracking data to the server in the background without interrupting user's navigation. The predefined use model of each communication activity allows the traces collectors on both client and server to exchange the information and to make the information coherent, e.g., the server is capable of synchronizing the tracking data submitted from clients with those on the server.

## 4.2 Tracking data of a use scenario

A number of tests were made with different use scenarios on contextual forum CONFOR (George & Labas, 2007). The tests focused on the following activities: (i) Browsing the forum structure, (ii) Posting new messages in forum, (iii) Replying to messages in forum, and (iv) Reading message in forum. We used a centralized database server as trace repository. It contains the meta data used for structuring the recorded tracking data and the tracking data that are submitted from the traces collectors on both client and server side.

The tracking data stored in the trace repository are originally in relational format. They can be transformed and exported into other formats of representation, such as RDF/XML, TXT, etc.

ID	User	Activity	Attribute	Date	Time	Delay	RefID
8094	Lucas	Connection	Login=Lucas82	19/06/2007	02:05:10		
8095	Lucas	Browse a course/forum structure	IDForum=4586	19/06/2007	02:05:22		
8095	Lucas	Visit a hypertext	Link=Help	19/06/2007	02:05:27		
8096	Lucas	Display a message in forum	IDForum=4586, IDMsg=68	19/06/2007	02:06:03	00:03:26	
8097	Lucas	Move scrollbar downward	IDForum=4586, IDMsg=68, Scrollbar=Vertical	19/06/2007	02:07:18		8096
8098	Lucas	Move scrollbar downward (reach the bottom)	IDForum=4586, IDMsg=68, Scrollbar=Vertical	19/06/2007	02:08:49		8096
8099	Lucas	Reply to a message in forum	IDForum=4586, IDMsg=263, IDMsgParent=68	19/06/2007	02:09:35	00:04:39	
8100	Lucas	Browse a course/forum structure	IDForum=3402	19/06/2007	02:14:20		
8101	Lucas	Post a new message in forum	IDForum=3402, IDMsg=270, IDMsgParent=null	19/06/2007	02:14:36	00:02:40	

Figure 4. Tracking data of communication activities performed by a user *Lucas*

Figure 4 presents a portion of the recorded traces of one among other use scenarios that consists of user's activities on server side as well as user's interactions on client side. If we look attentively at the recorded tracking data, we can find some significant information that reflects the whole activity of a user within a communication activity. As an example, the trace `IDTran=8096` explains that user *Lucas* displayed a message `IDMsg=68`, in the *forum* `IDForum=4586`. Such information can be a bit vague and might not be so advantageous to the teachers. Thanks to other descriptive trace indicators, we are able to know more about what this user did after having displayed the message in forum. As found in the "delay" data property, this user spent 3 minutes and 26 seconds to display (or probably read) the message before performing another activity. Furthermore, via the trace `IDTran=8097` and `IDTran=8098`, we can see that the user moved the vertical scrollbar downward to display other part of the message. This user also kept moving the vertical scrollbar till the bottom of the message. All of these trace indicators can be very substantive for the trace analysis and helping the teachers make better assumption on student's activity (e.g. reading a message in forum).

"How do we know whether or not a displayed message is read?". This question has been frequently asked, particularly by the teachers who regularly use discussion forums in their teaching activities. We are not pretending that we can prove if a message was really read by the user who displayed it, but we can tell if a message has not been entirely read. It is apparently that if a user has only rapidly displayed the message (e.g. less than 3 seconds) without touching or moving the vertical scrollbar downward the bottom of the message, but performing another activity instead (e.g. clicked on another message), the displayed message must not have been entirely read by the user. Back to the recorded tracking data shown in figure 4, a user (*Lucas*) might have read till the end of the message since he has not only displayed the message, but also moved twice the vertical scrollbar downward and to the bottom of the message, and besides, he has spent 3 minutes and 26 seconds on it (i.e. the windows that displays the message has been active right after the message was displayed and the user has not performed another activity within 3 minutes and 26 seconds). Providing such synthetic information and with every little detail of the activity is very useful for the teachers and a lot better than giving only the statistical data like the number of hits on the message, or which user clicks on which message, etc.

## 5. CONCLUSIONS AND FUTURE WORK

In this paper, we addressed the research challenges in tracking user's activities on Computer Mediated Communication (CMC) tools and in exploiting the tracking data to assist the participants in the learning process. The principal contribution of this research work is an approach for efficiently tracking user's communication activities on CMC tools. We presented the different levels of Human and Computer Interactions, where the observation must be carried out in order to collect as rigorously as possible the necessary information about the Computer Mediated Communication activities, including the content of the



exchanged communications. The biggest advantageous of giving a closer look at each level of Human-Computer Interactions is to enable the tracking system to generate the tracking data with finer granularity and with more significant indicators that can be of benefit to the participants in the learning process as well as the researchers and the CMC-tool developers. To prove the feasibility of the tracking system, we have developed a Web-based system, which is for now capable of tracking three levels of interactions: Human-Computer Interactions, Human-Human Interactions Mediated by Computer, and Computer-Computer Interactions.

After a huge number of tests that we made on our Web-based tracking system, we are willing to conduct some experiments with students and teachers in real distance learning situations. The experiment will be carried out within the learning session, where students and teachers employ both synchronous and asynchronous communication tools to make the discussion between them. One of the main objectives of the experiments will be to observe how efficient the tracking system is and what kind of collected data that can be useful to the participants in the learning process, both learners and instructors. We are currently developing a Web-based platform for traces management by hopping to provide more convenient supports to the teachers in the task of analyzing and visualizing the learners' tracking data. The trace analysis component will be implemented with both interaction and content analysis methods and the trace visualization component will be designed and integrated into the platform to help the teachers view the learner's tracking data in graphical presentations and evaluate different aspects of the learner's activities.

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