A TOOL TO SUPPORT INTERACTION AND COLLABORATION ANALYSIS OF LEARNING ACTIVITIES

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ABSTRACT
An increasing amount of data is collected today during studies in which students and educators are engaged in learning activities using information technology and other tools. These data are indispensable for analysis and evaluation of learning activities, for evaluation of new tools and for students' meta-cognitive activities. The data can take various forms, including video and audio recordings, log files of computing-related activity, field notes, results of students work in electronic or other forms, activity sheets etc. The need for analysis tools, which can annotate these data, classify them, process them and facilitate their inspection, is of increased importance especially for science education, since the latter involves experimentation and use of laboratory and other equipment that necessitate thorough off-line analysis and evaluation.
In this paper we discuss first the key requirements of a new generation of interaction and collaboration analysis tools. We then present how these requirements have lead to the design of a prototype tool, recently developed. This tool can relate and synchronize various streams of field data. An important characteristic of the tool is its support for a multi-layer structure of annotations of various levels of abstraction, through which the activity can be interpreted and presented. This multi-layer representation can be inter-related to the raw field data, and can drive the navigation of the researcher in the activity data. An example of use of this tool for analysis and evaluation of a collaborative problem solving activity is also included.

KEYWORDS
Behavioural analysis tools, computer-supported collaborative problem solving, video and logging of learning, evaluation of problem solving

INTRODUCTION

Tools to support interaction and collaboration analysis have been proposed in the field of human-computer interaction and learning technology design for many years now (Dix et al., 1998). In the educational field, analysis of collaboration and interaction between the actors (students, tutors etc.), the artefacts and the environment is a process that can support understanding of learning, evaluate the educational result and support design of effective technology. Data have been collected from field studies in various forms since the early days of education science. However it is the introduction of information and video technology that have accelerated the process and resulted in a proliferation of data sources and formats.

Stream media like audio and video as well as notes and comments of observers are used in ethnographic studies with emphasis in situated learning approaches. In the case when information technology equipment is used to support learning and to mediate in communication and collaboration, discrete data items in digital form are also produced. These are files containing solutions to problems and students' essays, logfiles of keystroke activity of

the actors interacting with educational tools, etc. These data need to be correlated and processed in order the researchers and educators to extract useful patterns of behaviour of the actors involved, identify usability and conceptual flaws in the design of the tools used and evaluate the educational approaches that have been pursued. This analysis process has become tedious, since the high volume of data has made this task more time-consuming and complex. The researchers run the risk of being flooded by enormous amounts of data, that hide useful information and knowledge. The need for adequate tools that support the analysis process has therefore increased.

These analysis support tools should preferably have the following characteristics: they should be independent of the analysis methodology used, they should be able to accommodate and integrate multiple data formats, they should be easy to use by the typical education research staff and analysts, they should be inter-operable with external statistical analysis and other data processing tools. They should also produce their results in various formats and should have flexibility in supporting multiple views over the data, similar to that of an information data warehouse, as these data can become the main repository of information for an educational research group and need often to be re-visited over and over again, under different research perspectives.

The design of an experimental environment that meets these requirements has been the focus of the research reported here. This research effort, has been inspired by aspects of human-computer interaction and user interface design, and is based on our own experience with analysis of behavioural data from complex settings, involving users and computing equipment. Since the main area of our applications is that of learning technology, we have developed during the last years a number of tools to support design and evaluation of interactive learning systems, see Tselios et al. (2001, 2002), Avouris et al. (2002, 2003b) etc. In this paper, we build on this experience by describing the functionality of a new integrated environment of analysis of learning, the *Collaboration Analysis Toolkit* (ColAT), which integrates multiple sources of behavioural data of multiple logging and monitoring devices.

The main emphasis of the ColAT environment is on the analysis of situations involving more than one learning actors. Special attention has been put on scenarios of synchronous computer-supported collaborative learning, in which the actors are spatially dislocated, a factor which imposes additional complexity in the analysis task. The ColAT environment has been originally developed as a support tool of the new collaborative modelling environment *ModellingSpace*, discussed in Avouris et al. (2003b) and Margaritis et al. (2003). However the design specifications of ColAT took special care to handle more generic requirements and for this reason this analysis environment is proposed here as a general-purpose tool, independent of the ModellingSpace environment.

In the specific case of analysis of computer-supported collaborative learning situations, many analysis methods have already been proposed and applied. Examples are the networked collaborative concept mapping system CRESST (Chung et al., 1999), the group action-driven interaction analysis of Muehlenbrock & Hoppe (1999) the C-CHENE system (Baker et al., 1999), and the BELVEDERE 2, for collaborative scientific inquiries (Suthers, 1999), which are based on dialogue analysis, while analysis methods based on both dialogues and actors actions have been proposed by Suthers et al. (2001), Soller et al. (2000), Avouris et al. (2002), Avouris et al. (2003a). However no specific tools have been reported in support of these approaches. On the other hand, in the more general context of interaction analysis, many task analysis and cognitive analysis techniques, have been proposed, like the GOMS family of techniques and tools (e.g. John and Kieras, 1996), with special recent examples the Cognitive Modelling Tool (Tselios and Avouris 2003) Concurtasktrees Tool (Paterno et. al 2000) and Euterpe for GroupwareTaskAnalysis (Van Welie et al. 1998). However these tools do not handle field data, but rather they are used for design purposes.

The proposed here ColAT environment attempts to cover this lack of tools and is proposed as a generic toolkit that can be used in the frame of many of the above methods of analysis.

In the following section the main features of the ColAT environment are discussed, subsequently an example of use of the tool is provided, followed by a discussion on the implications of this research for our field and the perspectives of this effort.

THE COLAT ANALYSIS ENVIRONMENT

The *Collaboration Analysis Toolkit (ColAT)* is a software environment to be used for off-line analysis and processing of field data, collected during learning activities. While the emphasis and the prime objective of this environment is in supporting analysis of data of collaborative problem solving activities, there is no inherent limitation to the use of ColAT for other types of educational activities and more general ethnographic studies.

Input Data

The data that can be processed by this toolkit are the following:

(a) stream data of video and audio of various digital formats (.mpeg, .avi .mov)

(b) logfiles that contain sequences of events that follow a simple generic format : <timestamp, offset, user_ID, action_type, arguments> and are in XML or ASCII form

(c) text files in .rtf format, containing field notes and observations

(d) image files containing screenshots of interim or final solutions to problems, as produced by the students, or artefacts constructed, in .bmp, .jpg, .png formats

These data are inserted in the ColAT environment and are interrelated through a so-called *ColAT project*

In figure 1, an example of the contents of such a ColAT project are shown, comprising various stream-data files and discrete events logfiles, as well as text files and image files.
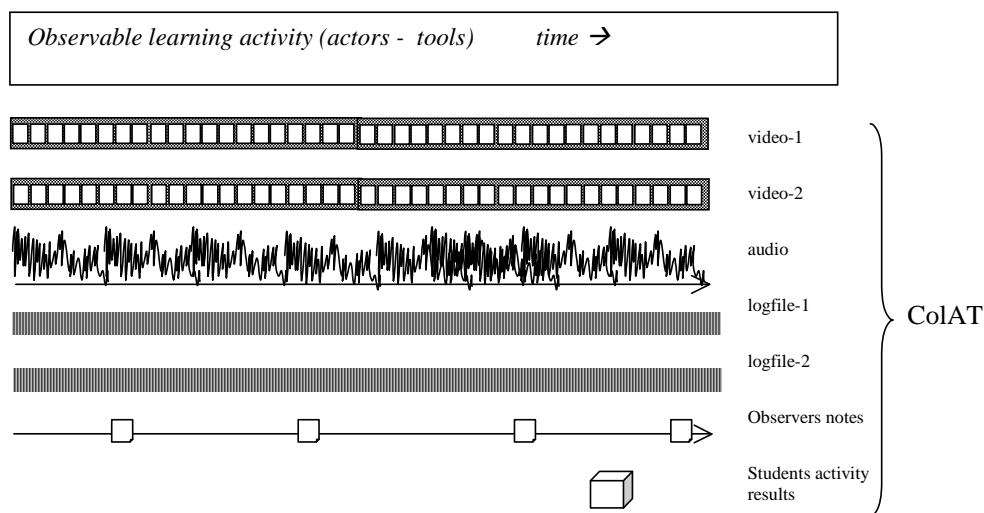

Figure 1: Sources of data of a ColAT project

Data interrelation

The user view over these data, is based on the *time-line of the events*. So a *master logfile* is created, in which all the logfiles are merged, sorted according to their time stamp attributes. This becomes the reference source of the project. Special attention should be paid in synchronizing these logfiles during this process, since the different time stamps might not be

fully synchronized, if they have been produced by different equipment. In this case an offset might be added to one of the logfiles, which is determined by inspecting the time stamps of events that have taken place at the same time and can be found in the logfiles. The problem of synchronization of different sources of monitoring is a very important one, and occurs more often in today's distributed environments, when often a virtual classroom can be made of many distant learning actors, whose activities are monitored by separate non-synchronized equipment.

Once this *master logfile* has been built all stream data sources can be related to it, by assigning the <start time> and <end time> of the stream file to corresponding events of the master logfile. Also image files can be related to time stamped new events inserted in the logfile, that correspond to the time when the image was created or the screenshot was taken. At the end of this preparatory phase all information contained in the ColAT project should have been interrelated and therefore can be viewed by "playing back" the master logfile, while appropriate viewers can reproduce the associated stream data, i.e. video and sound.

Annotation of field data

The most important phase of analysis relates to the interpretation and annotation of the collected data, as well as generation of aggregate data of interpretative nature. An innovative feature of the ColAT approach is the support for creation of a multi-level structure that describes and interprets the logfile events. In figure 2 the concept of the multi-level logfile is shown.
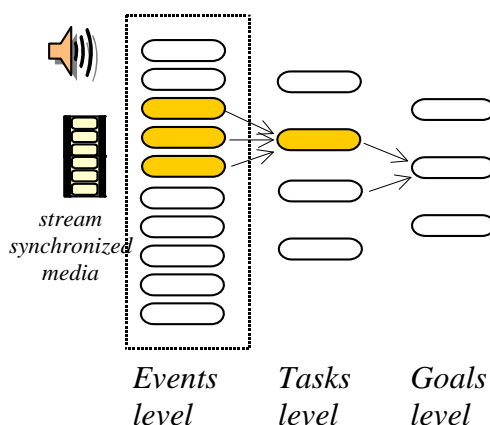

Events level   *Tasks level*   *Goals level*

Figure 2: The concept of the multilevel lofgile

The original sequence of events contained in the master logfile is shown as level 1 (*events level*) of this multilevel structure. The keystrokes or raw observations are included in this level. An example is the event "Student X selects option Y from the menu" in case of software use, or "Student Z said …."in case of a dialogue event. A number of such events can be associated to an entry at the *task level* 2 by the analyst. Such an entry can have the following structure:

< *ID, entry_type, comment* >

where *ID* is a unique identity of the entry, *type* is a classification of the entry according to a typology that has been defined by the researcher, followed by a textual comment or attributes that are relevant to this type of task entry. Examples of entries of this level are:" Student X inserts a link in the model", or "student Y contests the statement of student Z".

In a similar manner the entries of the third level (*Goal level*) are also created. These are associated to a number of entries of the previous task level. The entries of this level describe the activity at the strategy level as a sequence of interrelated goals of the actors involved.

An implication of this structure is that the associated stream media are related to this multi-level view of the activity and therefore the user of ColAT can decide to view the activity from any level of abstraction he/she wishes, i.e. to play back the activity by driving a video stream from the task level or the goal level. This resembles the situation, of watching a film and interpreting it at many levels, i.e. the details of the specific scene (at event level), the extracts of dialogue or activity (at task level) or the plot of the story (at goal level), while the summary of the story can be extracted from the top level, the details of interaction from the lower level and the interaction analysis is based on entries of the middle level.

This approach results in the design of a powerful tool, in terms of analytical power, since the possibility of viewing a process from various levels of abstraction, supports its deeper understanding and interpretation. It should be stressed at this point that the innovation of this approach is in the fact that it combines in a single environment the hierarchical analysis of activity, which has already been proposed and used by many frameworks of analysis, see Activity Theory, GOMS, HTA etc, to the sequential character of observational data, permitting easy navigation from one view of the process to the other

The ColAT *project* is stored in a database to facilitate processing and navigation of the source data and annotations. The integrated logfile should be able to be exported in XML form to other applications and data processing tools for further analysis.
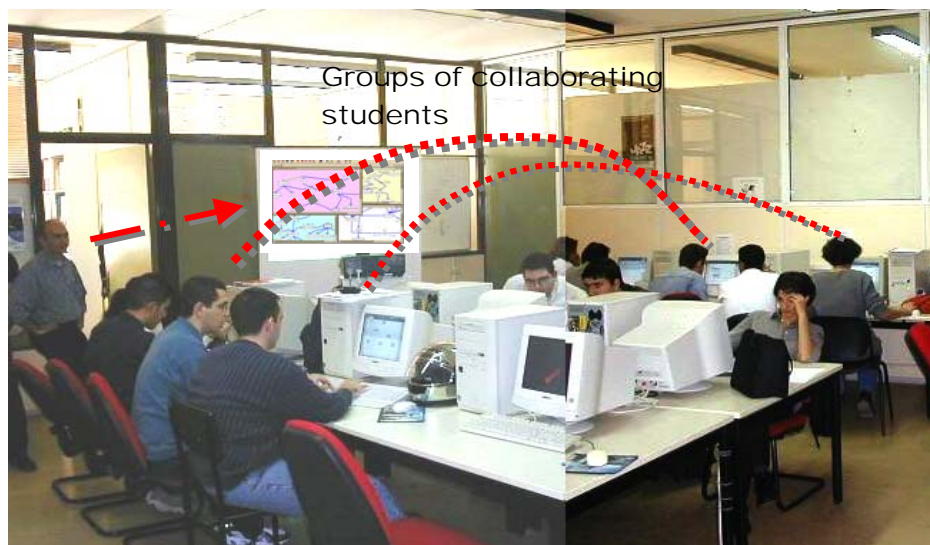

Figure 3: Setting of educational activity analysed by ColAT

COLAT CASE OF USE

In this section an example of use of the ColAT environment is presented. Through this example details of the user interface and the functionality of the environment are also discussed. The experiment concerns analysis of an educational activity that took place in the frame of a University Computer Science undergraduate course. In figure 3 the laboratory setting in which the experiment took place is shown.

Context of the experiment

The experiment took place in the frame of the laboratory of the undergraduate course "Data and Knowledge Based Systems" of the Electrical & Computer Engineering Department of the University of Patras. Twenty two (22) students participated in the experiment in the frame of a scheduled laboratory session that took place in two lab sessions. Eleven (11) groups of students with similar characteristics were formed, collaborating in pairs, five pairs in the first session and six of them in the second laboratory session. The members of the collaborating groups, were dispersed in the computer lab. They interacted for a certain period of time, using exclusively a Collaborative Modelling environment (chat tool and a shared drawing board) in order to tackle a given data-modelling problem in a simulated distance-collaboration setting. Each collaborating pair of students was asked to produce, by the end of the laboratory session, a single solution to the problem in the form of an Entity Relationship Diagram[1]. The tutor intervened mainly at the beginning of the session to introduce the activity and the tools, and at the final stage for making comments on some of the produced solutions. The activity was video-recorded and an area microphone was used to capture the discussion in the class. Also activity logging was performed using the logging facility of the collaborative modelling tool itself. The logfiles were produced in each student workstation (22 logfiles). The logfiles produced were of the form shown in figure 4. The types of events contained in these logfiles are shown in table 1.

#	Time 1	Time 2	User	Action	Attributes	
			Date: Δευ...		[]	▲
			User: U2		[]	
1	19:34:51	00:00:06	U1	Request for collaboration	[U1, 1, {unknown},...	
2	19:34:55	00:00:10	U2	Request for collaboration accepted	[]	
3	19:34:53	00:00:08	U2	Partner asked for the key	[]	
4	19:34:59	00:00:14	U1	Partner passed the key	[]	
5	19:35:07	00:00:22	U2	Insert sticky note	[note_1, 1, java.aw...	
6	19:35:09	00:00:23	U2	Move object	[note_1, java.awt.R...	
7	**19:35:10**	**00:00:25**	**U1**	**Chat message**	**[Hello!]**	
8	19:35:24	00:00:39	U2	Change sticky note text	[note_1, ApladasAp...	
9	19:35:26	00:00:41	U2	Move object	[note_1, java.awt.R...	
10	19:35:38	00:00:52	U1	Partner asked for the key	[]	
11	19:35:38	00:00:52	U2	Partner refused the key	[]	

Figure 4: Extract of the logfile of this experiment

Each logfile captured the events of the interface that were produced by the student user of the workstation, during the session. Since in each pair the students have been working together through the internet, the logfiles were symmetrical, the only slight differences observed in some cases when temporarily the internet connection was lost and the activity continued in a stand-alone mode for a short time. Once these periods were identified and the events captured, the partners logfiles were compared and merged, so at the end of this phase just 11 logfiles were produced, representing the activity of the 11 pairs of students. Thus the unit of analysis in our case became each single pair of collaborating students, in which we focussed. The video of the overview of the class, however failed to capture the details of activity at this level. We used this source of information for capturing events like the interventions of the tutors, which were inserted as additional external events in the pairs' logfiles.

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[1] ERD, i.e. Entity relation diagram, a form of a data model, representing entities and relations of a micro world

Event types	
Change concept relation text	Insert simple text
Change simple text	Insert sticky note
Change sticky note text	Move object
Chat message	Partner asked for the key
Delete object	Partner passed the key
Edit Entity details (Concept)	Partner refused the key
Insert Clipboard data	Request for collaboration
Insert Concept link	Request for collaboration accepted
Insert concept relation	Save model
Insert entity	Toggle description display

Table 1. Types of events in the logfiles

Capturing of interaction events on video
As discussed in the previous section, the video stream failed to capture the events at the level of the pairs of students. This is usually the case with large groups of students in a class setting. The video concentrates more on the tutor and misses the events at the level of small groups. In our case an alternative source of stream data was created, by playing back the logfiles by the modelling tool itself. This has been done through the relevant facility of the modelling tool used, shown in figure 5, discussed also in Avouris et.al. (2003c).
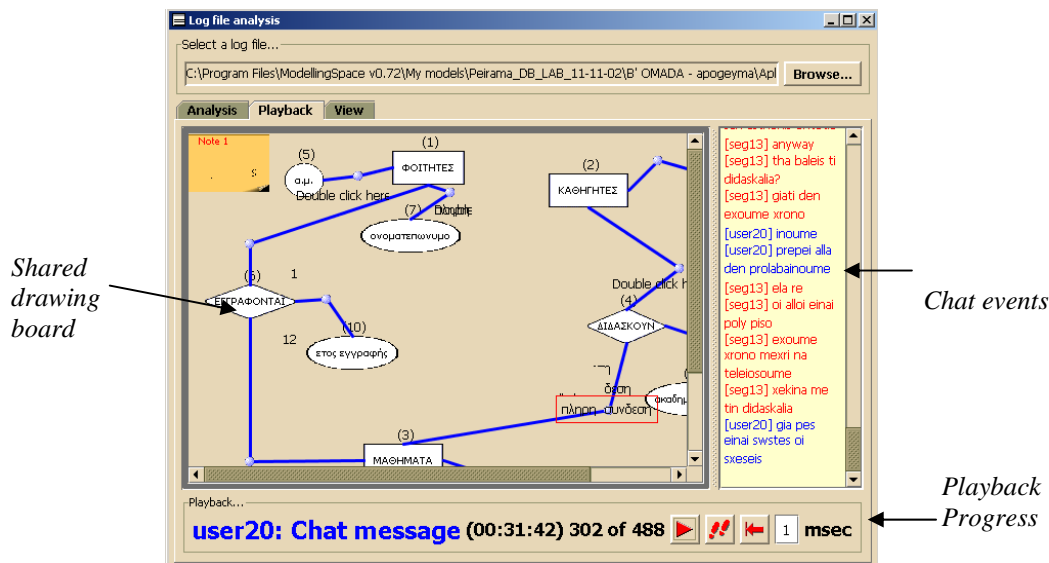

Figure 5: Playback of modelling activity from the logfile

In general screen capturing facilities, available with modern display devices, can be used to generate stream of information relating to the activity at the workstation display, which can be mixed to other sources of video and other media, overcoming the problem of monitoring at the single group in the context of a large class.

Generation of higher-level logfile entries
Once the pre-processing of field data has been completed, the higher-level logfile entries are created. The ColAT editor, the component of the environment through which this operation is effected, is shown in figure 6. In this case an event of task level 2 has been generated out of 10

events of level 1 (shaded events). The user selects the lower level events and creates a new entry in the higher level, which is associated to the selected lower level events.
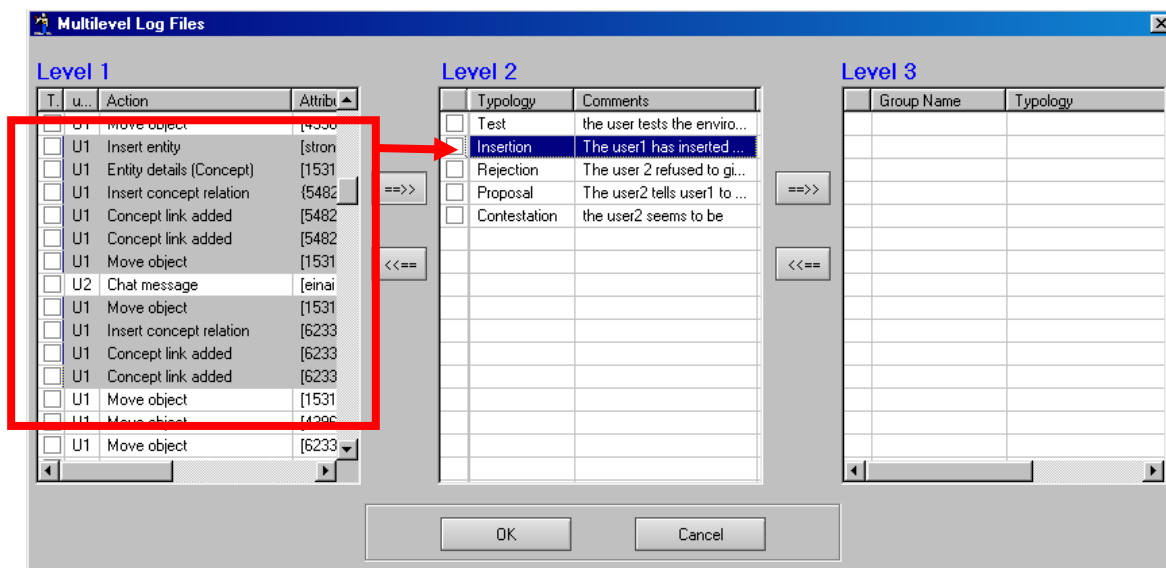

Figure 6: Creation of higher-level entries in ColAT

The lower level events that have been selected in this extract are the events 38- 48 in figure 7, except event [44], which is an event sent by user U2, not related to this specific task. In figure 7 the extract of the solution that relates to these events is shown. In this extract of an ER diagram, the objects that make up the Relation (TEACHES) and its connection to existing objects are shown.

Level 1 logfile
[38] U1-Insert entity-[strong relation, 5]
[39] U1-Entity details (Concept)-[5, "TEACHES"]
[40] U1-Insert concept relation-[6]
[41] U1-Concept link added-[6, 3]
[42] U1-Concept link added-[6, 5]
[43] U1-Move object-
[44] U2-**Chat message-**"Prof said this is an entity"
[45] U1-Move object-[5]
[46] U1-Insert concept relation-[8]
[47] U1-Concept link added-[8, 5]
[48] U1-Concept link added-[8, 4]

level 2 logfile
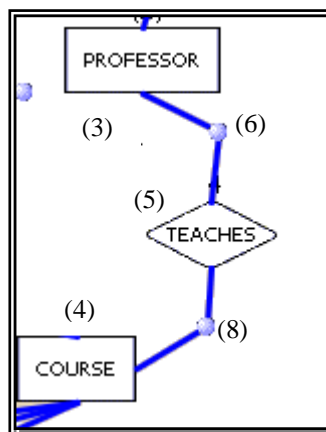[1] U1 Inserts Relation (TEACHES)

Figure 7: Example of generation of entry level 2 out of level 1 events

In this second level of the logfile the typology of the Object-Oriented Collaboration Analysis Framework (OCAF), see Avouris et al. 2002 and 2003a, has been used. This framework is particularly suitable for analysis of collaborative learning activity, which involves interleaving of actions and dialogue. OCAF puts emphasis on the objects of the jointly developed solution. Every object is assigned its own history of events (actions and messages) related to its existence. The history of each one of these objects is a sequence of events that refer to an actor and an action according to the following functional types:

I =   Insertion of the item in the shared space
P=   Proposal of an item or proposal of a state of an item

C= Contestation of a proposal
R= Rejection / refutation of a proposal
X= Acknowledgement/ acceptance of a proposal
T= Test/Verify using tools or other means of an object or a construct (model)

As an example of an OCAF event, the introduction of a new Relation in the model, described in this section, is indicated as *Relation (TEACHES)= I$_{U1}$*, i.e. User 1 inserted the Relation (TEACHES) in the shared space.
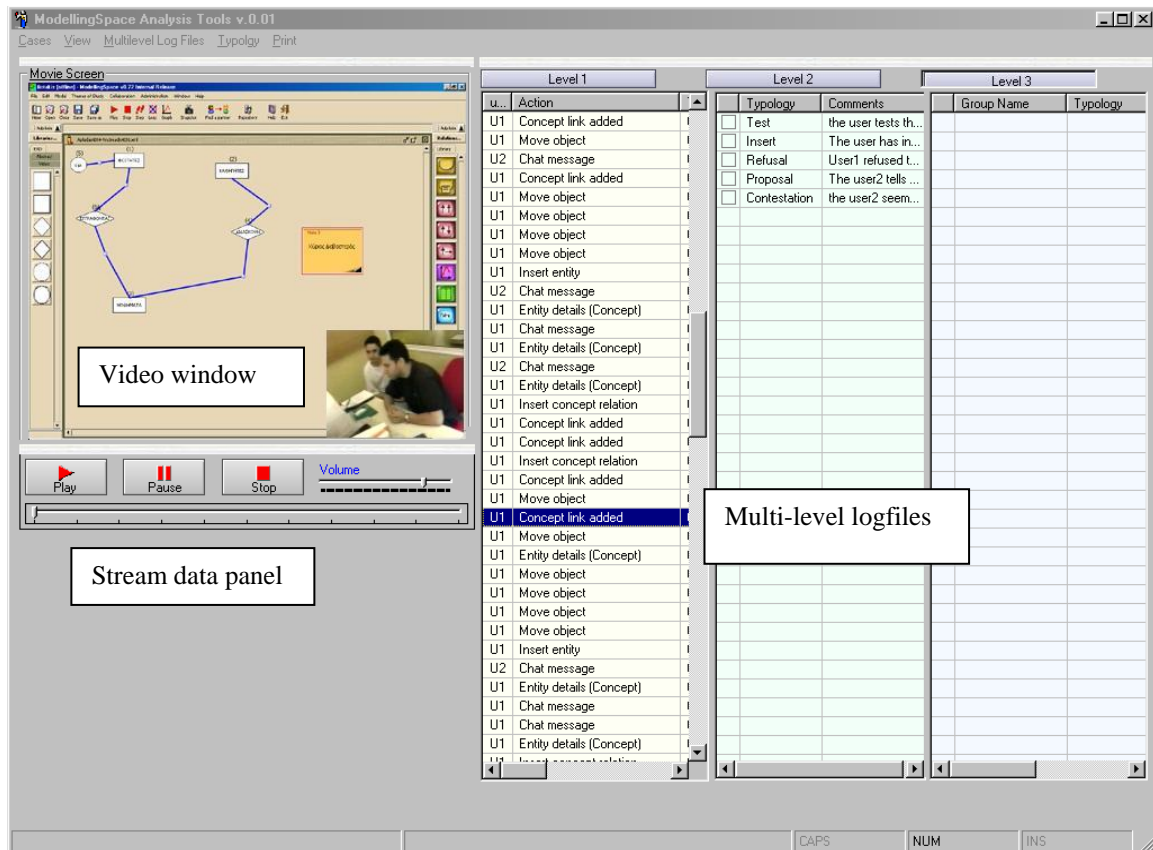

Figure 8: Overview of the ColAT data navigation environment

Navigation of field data

The ColAT environment that supports navigation of the constructed multilevel logfiles is shown in figure 8. A video window permits viewing of streaming data in association to selected events in any level of the logfiles. There are different modes of use of this environment:

(a) In the first mode, *navigation is controlled through the video*. When the *play* button is selected and the video proceeds, or the video handler from the video panel is dragged to any position of the selected video file, the corresponding event of the log hierarchy that the video is related to, is highlighted.

(b) In the second mode, *navigation is controlled from the logfiles*. In this case the user can select any event in the first level of the log file and the video starts from that event onwards. If an event of higher level is selected, then the video will move to the associated event and will start playing. The user can hide the levels of abstraction he/she wishes to ignore, thus defining the desired view over the field data.

The ColAT navigation tool has been proven particularly useful in analysing the data of the reported experiment, following the OCAF methodological framework.

CONCLUSIONS

This paper described the main functionality and a case of use of the Collaboration Analysis Tool (ColAT), an innovative environment that supports multilevel analysis of field data collected during learning activities. ColAT supports various kinds of field data and permits annotation of stream data. This is done through discrete event files, like logfiles, which are associated through time stamps to the stream data sources. Since the video plays an increasingly important role in educational activities and in particular as it is becoming a prime source of field educational data, the ColAT approach proposes a technique for smooth integration of video with other data sources. The multi-level annotation scheme described here permits change of point of view and relates the stream data to the annotations. These annotations can be either free text comments, transcripts of dialogues, or comply to a typology imposed by a methodological framework, like the OCAF scheme used in our example.

ColAT first version has just been released, as an experimental prototype. However the development and testing of the ideas related to this toolkit, have already invoked thoughts on further research. We are currently investigating the following future directions: we study the possibility of producing an XML multi-layer annotation scheme as a result of ColAT; it is under investigation the relation of the ColAT bottom up annotation of field data to top-down task level description of the observed activity (Tselios and Avouris, 2003); new proposed features are the presentation of the inserted comments as sticky notes on the video window, subtitling video through transcribed dialogues etc, while special effort will be put towards the direction of multiple semantics and existing standards related to logging of events.

The concepts and tools discussed here are relevant to researchers and educators who are involved in analysis and evaluation of learning activities, in design and evaluation of new tools and students' meta-cognitive activities. As a concluding remark, it should be stressed that findings of this area of research, can have a multiplying effect in science education, since powerful tools can help our research community mature and progress towards its objectives at a higher pace.

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