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An environment for studying collaborative learning activities

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Abstract

Studies of collaborative learning activities often involve analyses of dialogue and interaction as well as analyses of tasks and actors' roles through ethnographic and other field experiments. Adequate analysis tools can facilitate these studies. In this paper, we discuss key requirements of interaction and collaboration analysis tools. We indicate how these requirements lead to the design of new analysis environments. These environments support annotation and analysis of various kinds of collected data in order to study collaborative learning activities. An important characteristic of these tools is their support for a structure of annotations of various levels of abstraction, through which an activity can be interpreted and presented. This can serve as a tool for reflection and interpretation as well as for facilitation of research in collaborative learning.

Keywords

Collaborative problem solving, analysis of collaboration, ethnographic studies

Introduction

Collaborative learning is considered an active process that may lead to deep understanding from the students, to development of skills of critical thinking, to communication, coordination and conscious knowledge construction mechanisms (Dillenbourg, 1999). Analysis of a collaborative learning activity is important for understanding this complex process and improving the effectiveness of collaborative learning approaches. Collaboration analysis can also be used as a reflection-support mechanism for the actors involved.

Tools to support interaction and collaboration analysis have been used in the field of learning technology design and human-computer interaction (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. A number of tools and methodologies have been proposed, like those related to the Cool Modes environment (Gassner et al., 2003), and the combination of qualitative evaluation and social network analysis (Martinez et al., 2003), while a useful contribution to the field is made by Martinez, Fuente and Dimitriadis (1993) who proposed an abstract representation of collaborative action.

In this paper, we focus on tools for analysis of synchronous collaborative learning activities that are independent of a specific task and collaboration support environment.

Tools to support analysis

Recent theoretical advances in Computer Supported Collaborative Learning (Koschmann et al., 2002; Wasson et al., 2003) and the requirements that emerge from the filed, (like analysis of ineraction in the class, in working groups, analysis of chat and forums and so on), lead to the conclusion that effective analysis-support tools should be independent of the methodology used; they should, accommodate and integrate multiple data formats and, be easy to use by typical education researchers and analysts; they should, be inter-operable with statistical analysis and other typical data processing tools as well. They should also produce results in various formats and be flexible in supporting multiple views over the data, as these data can become the main repository of information for educational research which may be reviewed under different research perspectives.
The design of tools that meet such requirements is the focus of the research reported here. These tools support methodologies for design and evaluation of interactive learning systems (e.g. Tselios et al., 2003; Avouris et al., 2003).

In the following, we describe the functionality of a new environment for the analysis of group learning that integrates multiple sources of behavioural data produced by multiple logging and monitoring devices. This environment is made of two distinct components.

The first one, the *Activity Analysis (AA)*, handles history logfiles of activity and textual communication. Through this Activity analysis tool, the researcher can playback the activity off-line and annotate the produced diagrammatic solution. This environment produces quantitative measures of collaborative activity and permits visualization of actors and their roles off-line. There are similarities of the AA tool with the structural analysis components described in Gassner et al. (2003). AA has been associated originally to the collaborative modelling environment ModellingSpace (Avouris et al., 2003) and later to the collaborative flowcharting environment Synergo (http://www.ee.upatras.gr/hci/synergo). Both these environments support direct communication and problem solving activity of a group of distant students, manipulating a shared diagrammatic representation.

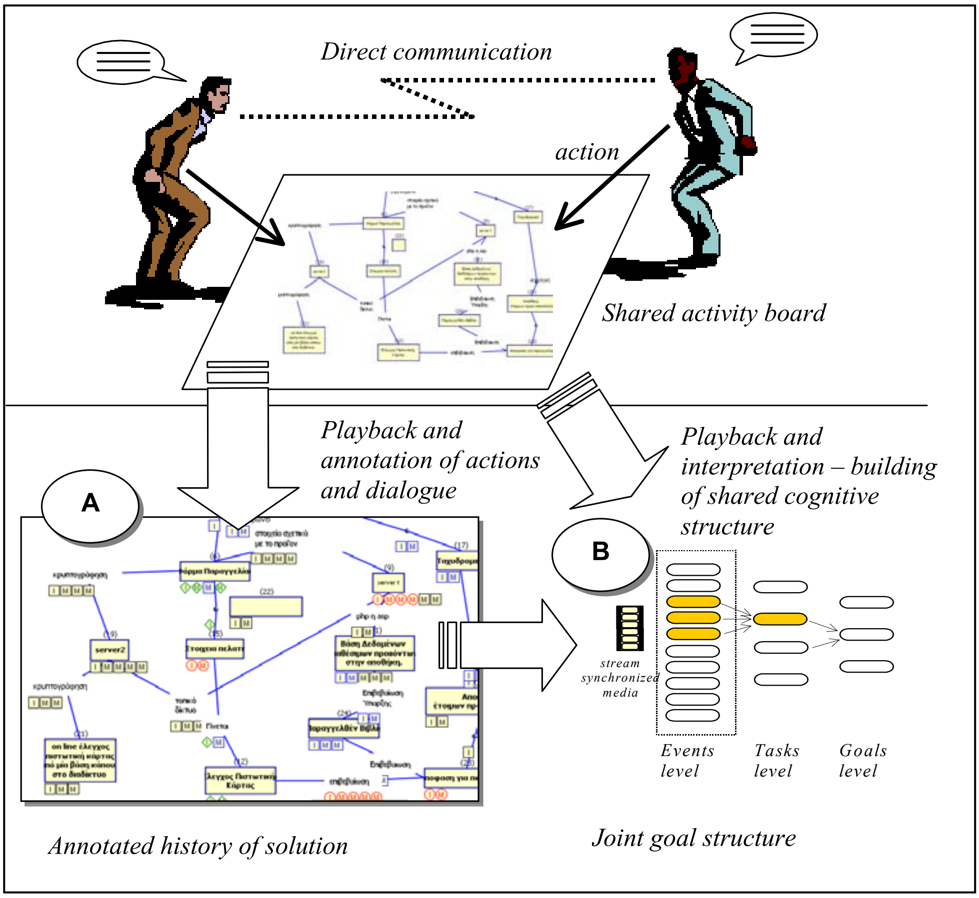

Figure 1. Overview of the analysis environment

The second one, called *Collaboration Analysis Tool (ColAT)* is a tool, independent of a specific collaboration support environment, to analyse multimedia data, collected during collaborative activities and review the activity by annotating the observed behaviour and building interpretative joint goal structures. This belongs to the general class of qualitative analysis tools, with special emphasis on analysis of collaborative learning activities.

The focus of the reported research has been put on study of scenarios of *synchronous* computer-supported collaborative learning, in which the actors are *spatially dislocated*, a factor which imposes additional complexity in the analysis task. In the following section, the main features of these analysis environments are described, followed by a discussion on the implications of this research for the field of technology-enhanced learning research and the perspectives of this research effort.

Method and tools of analysis

Overview

In Figure 1, an overview of the described analysis environment is outlined. In a typical synchronous collaborative learning situation, two or more actors, supported by networked equipment, collaborate at a distance by communicating directly and by acting in a shared activity board. A graphic or diagrammatic representation of a solution to a given problem may appear in this shared board. This activity is typically monitored through automatic logging of the main events and recording the activity of the actors in the shared activity board and of the dialogue events if they are in text form. Logging of events may also be done by observers, like "at 14:30 person X call viewed an animation created by person Y". In addition, the dialogue can be captured through video and audio recording if videoconferencing technology has been implemented, while additional information of the activity and the context within which this has taken place, may be captured in various forms (still images, textual observations, video and audio recordings etc.).

This setting may result in a large amount of data in various forms. In the following, tools for analysis of data collected in such collaborative situation and interpretation of the collaborative learning activity are described. The analysis framework involves two distinct phases and associated tools.

Activity Analysis

During the first phase of this analysis process, the *Activity Analysis* tool is used for visualization and processing mainly of the history logfiles, produced during collaborative learning activities. These logfiles contain time-stamped events, which concern actions and exchanged text messages of partners engaged in the activity, in sequential order. These events have this typical structure:

<time-stamp>, <actor>, <event-type>, <attributes>, <comments>

The logfile events are produced by exchanged control and textual dialogue messages and need to adhere to a defined XML syntax. These events can be viewed, commended and annotated by the tools discussed here. The activity can be reproduced using the *Playback Tool* that reconstructs the group problem-solving activity on the students' workstations desktop step by step, through a single view. Annotation of the events is done, according to specific analysis models that permit building of an abstract view of the activity.

OCAF : An example of an annotation scheme

An example of an annotation model that can be used by Synergo is the *Object-oriented Collaboration Analysis Framework* (OCAF) (Avouris et al., 2003), which is particularly suitable for analysis of collaborative problem-solving activity. The activity playback and solution annotation tool is shown in Figure Figure 2. The result of this phase is an annotated history of the problem-solving activity and of the produced diagrammatic solution. In the example ofin Figure Figure 2 one can see the graphic representation of this history and annotation of the solution in the shared activity board. In a separate window, the history of textual dialogue events is presented. Each item of the diagrammatic solution of a problem (a concept map representing a web service in this case) is associated to the sequence of events that lead to its existence. So the sequence (I),(C),(M),(R) (Figure 2) represents the following events: *(I)nsertion* of this object by actor A, *(C)ontestation* of this insertion by Actor B, *(M)odification* of the object by Actor A and *(R)ejection* of the modification of Actor B. This view of the activity depicts the intensity of collaboration in relation to specific parts of the diagram and identifies the collaboration patterns of the activity.

AA support for automatic annotation of collaborative learning activity

Generation of the annotated view by interpreting one by one the history logfile events is a tedious process; the AA environment facilitates this process, by allowing association of the events, automatically generated by the collaboration support software, to classes of annotations. So for instance, all the events of type *"Modification of concept text"* in a concept-mapping tool are associated to the *"Modification"* annotation of the OCAF scheme.

Not all events however can be automatically annotated in this way. For instance, textual dialogue messages need to be interpreted by the analyst and, after establishing their meaning and intention of the interlocutor, they need to be annotated accordingly. So for instance, a suggestion of a student on modification of part of the solution can be done either through verbal interaction or through direct manipulation of the objects concerned in the shared activity board. OCAF proposes a uniform scheme for annotation and interpretation of action and dialogue events. The new annotated logfile can be inserted in the ColAT environment, used subsequently in the second phase of analysis, is discussed in the next section.

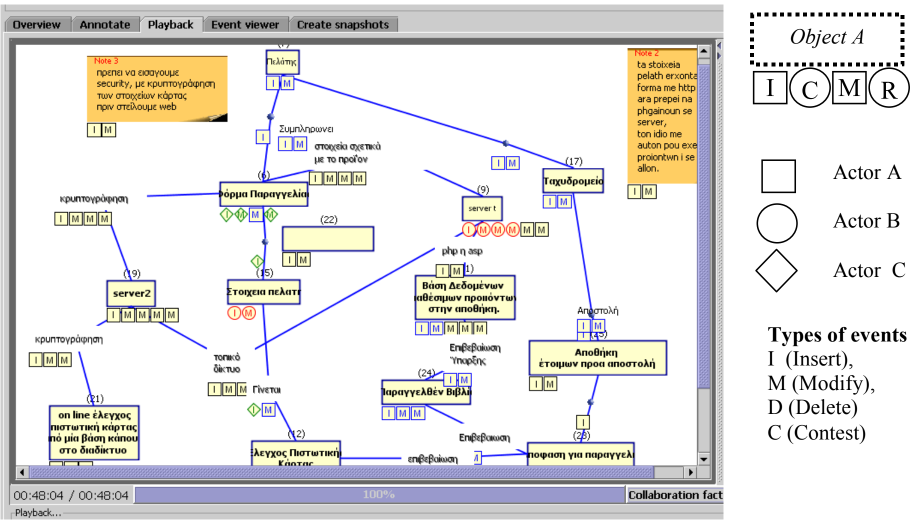

Figure 2. A jointly built model, annotated according to the OCAF scheme.

(a)

(b)

(c)

(d)

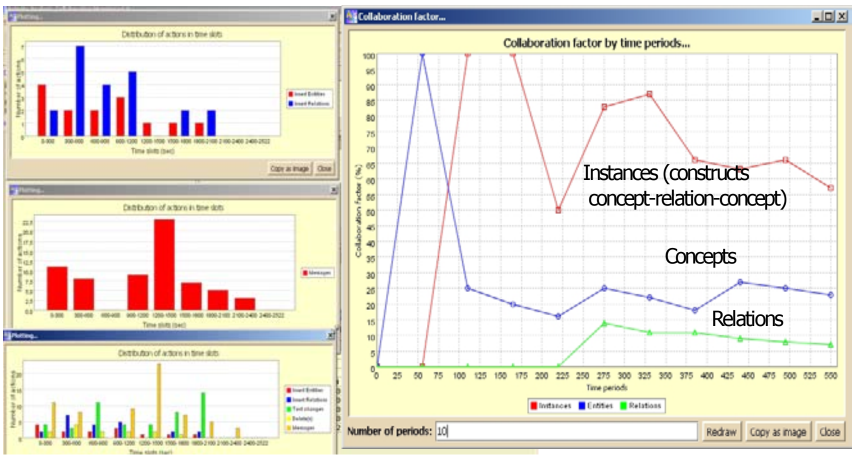

Figure 3. Charts of evolution of collaborative activity. (a) insert and delete activity, (b) chat messages, (c) mixed view, (d) collaboration factor

Statistics of collaboration, the collaboration factor

Additional views can be generated, that represent the collaborative process. These are statistics of collaboration activity per time slot of activity. Another view relates to the graph of evolution of the *Collaboration Factor (CF)*. This is an index, which is calculated from the patterns of collaboration that generated the solution. CF takes higher values if most components have been built with contribution of all partners, while it is low if there is no joint contribution of the partners in construction of parts of the solution.

In figure 3 some typical views are shown, which depict the evolution of various types of events during the activity. So in chart (a) of Figure 3 one can see the evolution of the *Insert* (red) and *Delete* (blue) events in the shared activity board, while in chart (b) of the same figure the textual messages exchanged in the same study. Through these views, one may observe the level of activity during various phases of problem solving. In our example, is shown that during the fifth time period, the partners involved were more engaged in verbal interaction than acting in the shared activity board.

Collaboration Analysis

In the second phase, the *Collaboration Analysis Tool* (ColAT) is used for building an interpretative model of the joint activity in the form of a joint plan or sequence of pursued goals, as they may be produced by the observed behaviour. ColAT permits fusion of multiple data by interrelating them through the concept of universal *activity time.* The analysis process during this phase, involves interpretation and annotation of the collected data, which takes the form of a multilevel description of the collaborative activity.

The ColAT tool, discussed in more detail in (Avouris et al., 2003c), uses a theatre scene as an organizing metaphor and framework. According to this, one can observe the action by following the plot from various standpoints. The event-view permits study of the details of action and interaction, the task-view permits study of purposeful chunks of action, while the goal-view studies the activity at the strategic level, where most probably cognitive processes of the actors and the decisions on collaboration are more clearly depicted.

This three-level model is built gradually: the first level, the *events level*, is directly associated to log files of the main events and is related through the time-stamps to the stream media like video. The second level describes *tasks* at the actor or group level, while the third level is concerned with *goals* of either individual actors or the group. In Figure 3 the typical environment of the ColAT tool for creation and navigation of a multi-level annotation and the associated stream media is shown. The three-level model is shown on the right, while the video/audio window is shown on the left.

The original sequence of events contained in the logfile is shown as level 1 *(events level)* of this multilevel model. The format of events of this level in XML, is that produced by the AA environment. Thus the output of the first phase can feed into ColAT, as first level structure. A number of such events can be associated to an entry at the *task level 2*. Such an entry can have the following structure: *<ID, time-span, entry_type, actor(s), comment >,* where *ID* is a unique identity of the entry, *time-span* is the period of time during which the task took place, *type* is a classification of the entry according to a typology, defined by the researcher, followed by the *actor* or actors that participated in the task execution, 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 ", or "student Y contests the statement of Z".

In a similar manner, the entries of the third level (*Goal level*) are also created. These are associated to 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 or jointly decided. This is an appropriate level for description of plans, from which coordinated and collaborative activity patterns may emerge. In each of these three levels, a different typology for annotation of the entries may be defined. This may relate to the domain of observed activity or the analysis framework used. For entries of level 1 the OCAF framework may be used, while for the task and goals level different annotations have been proposed.

Multimedia in ColAT

Various streaming media, such as digital *video* or *audio* files can be viewed using the ColAT tool from any level of its multi-level model of the activity. As a result, the analyst 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 or the goal level. This way the developed model of the activity is directly related to the recorded field events.

Other media, like still images of the activity or of a solution built, may also be associated to this multilevel model. Any such snapshot may be associated through a timestamp to a point in time, or a time slot, for which this image is valid. Any time the analyst requests playback of relevant sequence of events, the still images appear in the relative window. This facility may be used to show the environments of various distributed users during collaboration, to illustrate the use of tools and other artefacts, and so on.

The possibility of viewing a process using various media (video, audio, text, logfiles, still images), from various levels of abstraction (event, task, goal level), is an innovative approach. It combines in a single environment the hierarchical analysis of a collaborative activity, which has already been proposed and used by many frameworks of analysis, like Activity Theory (Nardi 1996), Goals, Operators, Methods and Selection (GOMS, John, and Kieras, 1996), Hierarchical Task Analysis, (Hollnagen, 2003) to the sequential character of observational data.

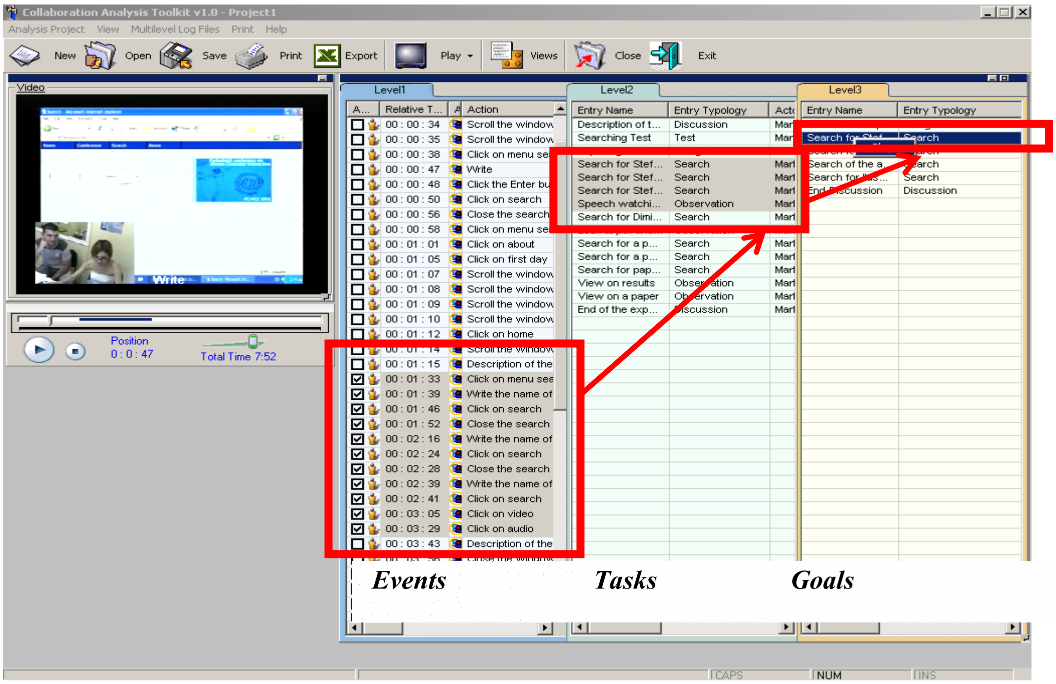

Figure 4. Navigation of multi-level log of collaborative problem solving activity

Experimental studies

A number of experimental studies have been recently performed using these tools. These relate to various aspects of collaborative learning and problem solving. In Fidas, Komis, Tzanavaris, Avouris (in press) the effect of heterogeneity of the available resources has been studied for various collaborative-learning experiments. In Avouris and colleagues (2003d) the effect of the floor control mechanism is studied, while in Komis, Avouris and Fidas (2002) evaluation of the effectiveness of the environment in the educational process is discussed along various dimensions, like group synthesis, task control, content of communication, roles of the students and the effect of the tools used. In these studies, various versions of the presented tools have been used. First the Activity Analysis (AA) tool has been used for playback and annotation of the activity, while statistics and estimation of the collaboration factor have been produced. Subsequently the produced video and sequences of still images, along with the History logfiles of the studies were fed in the Collaboration Analysis (ColAT) environment through which the goal structures of the activities were constructed.

These studies demonstrated that there are many issues, relating to collaborative learning, that necessitate further research. So, experimental tools are needed to support and facilitated such studies. For this reason analysis tools, like the ones presented here, can be useful means towards a better understanding of the issues, related with collaborative learning.

Conclusions

In this paper, we outlined the main features of two new tools that facilitate analysis of complex field data of collaborative problem solving activities, the *Activity Analysis (AA)* and the *Collaboration Analysis Tool* (ColAT).

The first one, a playback and solution annotation tool permits re-construction of the problem solution and visualisation of the partners' contribution in the activity space. AA is a tool that automates processing of history logfiles and puts emphasis on quantitative analysis.

The second tool supports building a multilevel interpretation of the solution, from the observable events level to the cognitive level in combination with multimedia view of the activity. Through this, a more abstract description of the activity can be produced and analysed at the individual as well as the group level. This tool combines multiple points of view and follows the qualitative analysis tradition.

It should be observed that the two presented tools are complementary in nature, the first one, used for building annotation of the problem solving at the event level, while the second one leading to more interpretative structures. The result of the first phase can feed the second phase, in which case the first level of the multilevel structure is already filled. The higher levels are in this case built, using ColAT. However the two tools are quite independent since their use depends on the available data and methodological framework of analysis. The first one has been so far tightly linked to the specific synchronous problem-solving environments, while the ColAT is more generic and can be used for studying any kind of collaborative activity, which has been recorded in multiple media.

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