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Collaboration Activity Function: An interaction analysis tool for Computer Supported Collaborative Learning activities

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Abstract

During the last years an increased interest has been observed on tools analyzing collaborative interactions that could be useful for researchers, teachers, or even students. The paper presents such a tool, based on the formally defined Collaborative Activity Function (CAF). The empirical evaluation of CAF is also presented. The evaluation is focused on teachers using CAF during and after sessions of synchronous collaborative problem solving among students.

1. Introduction

Collaboration is the co-construction of knowledge with the mutual engagement of participants [3]. Computer supported collaborative learning is focused on the enhancement of peer interaction, groups' working, and the facilitation of knowledge sharing and distribution [3]. Consequently, collaborative learning environments should analyze collaboration and provide this information to participants in order to really support them. This includes both the content level and the interaction/collaboration level.

Some collaboration analysis' methods process the collaborative discussions or dialogues facing natural language understanding problems [4], [5]. In [6] a different approach is described, in which the collaboration analysis uses dialogues along with common workspace's information. Finally, in [7] learners' human computer interface actions in combination with problem solving plan recognition techniques have been used as input material, without any dialogue analysis.

As far as the limitations of the above analysis method are concerned, the linguistic analyses are of different nature and depending on a classification of dialogue acts, which is not fully automatic [1]. In addition, plan recognition techniques cannot be applied to all domains and are not so usable.

In this paper, we focus on teacher's role during synchronous collaborative problem-solving, where the teacher observes students' interaction in real-time and intervenes in order to help them. This area of study is worthwhile because teachers need support to attend many groups at the same time and estimate quickly the evolution of the collaboration.

For the above need, we propose a collaboration analysis tool, which fulfills the following initial requirements: (1) Easy detection of interesting groups' situations, (2) Real time availability during the collaboration, (3) Adaptable abstraction level on demand, (4) Adaptable information volume presentation, on demand. This tool is to be used independently or in conjunction with other analysis' tools that collaborative systems may incorporate, such as ModellingSpace [9], or COOLModes [1].

2. CAF definition

2.1. The collaboration framework model

In order to prepare the CAF definition justification, it is useful to describe the collaboration schema for which CAF was initially designed. CAF has been devised during pedagogical validation research of ModellingSpace* (MS). This is a collaborative modeling environment for distributed development of models that supports the logical collaboration topology of figure 1.

In ModellingSpace, agents (agent:=[student| teacher| researcher| software]) can exchange chat messages while they develop a model in a common workspace. The communication mode is synchronous

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since the availability of all the participants is required. As was previously mentioned, teachers and researchers need a tool to help them estimate the collaboration level, the progress rate and, in general, the state of the agents' group.

In figure 1 we see that agents collaborating using MODELLINGSPACE communicate through a set of logical broadcast channels. Each channel uses a different application level communication code. Agents' interactions are expressed as application level messages. Making use of this abstract schema for the collaboration using MODELLINGSPACE we are ready to present the main hypotheses behind CAF definition.

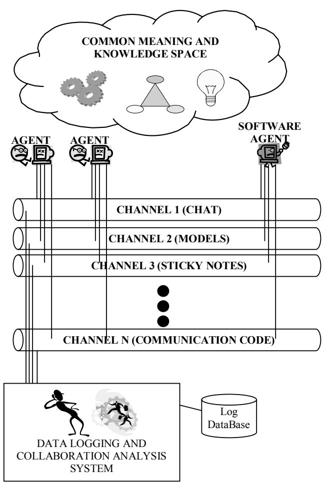

Figure 1. Logical topology of synchronous collaboration

2.2. Basic hypotheses

H1. The collaborative action in any time interval is proportional to the agents that were interacting during it. More specifically, for the time interval $\Delta t_i = t_i - t_{i-1}$ the collaborative action is proportional to the number of agents that have posted at least one message in any of the communication channels.

$$CA(t_i) \sim Agents(t_i)$$

In some cases, the above claim has not got good estimation accuracy. For example, it is possible that for a relative long interval only one agent to be possible to act. In addition, it is possible that many agents post messages irrelevant to the goals of collaboration (e.g. just chatting). As will be clearer in the followings these limitations can be practically handled.

H2. The collaborative action in any time interval is proportional to the total number of interactions that have been realized.

More specifically, in the time interval $\Delta t_i = t_i - t_{i-1}$ the collaborative action is proportional to the total number of messages that have been posted through the communication channels of MS (Interactions).

$$CA(t_i) \sim Interactions(t_i)$$

H2 claims that the more the messages posted in a time interval, the more the collaborative action of the group. In some cases, H2 is also not so accurate. For example, it is possible for many messages to be posted in an interval from a unique agent.

H3. The limitations of H1 and H2 can be controlled estimating the collaborative action in an interval by the product of active Agents to their Interactions.

$$CA(t_i) \sim Agents(t_i) * Interactions(t_i)$$

H3 claims that between two intervals with the same number of active agents, there is more collaborative action in the interval with more interactions.

2.3. Design choices

Except of the above hypotheses behind CAF definition there are some design options that are imposed by the user requirements (see next section). More specifically:

The estimation of collaborative action should be feasible during the agents' collaboration (online): In order to fulfill this option, time is divided in equal length slots (quantums). CAF is calculated at the end of each time slot.

The evaluation of CAF should be possible to be analyzed to the available channels and/or agents: In order to analyze the collaboration contribution of each channel, CAF should have a modular structure with a clear separate module for each channel and agent. This feature permits qualitative estimations of the collaboration while it facilitates the assessment of each agent's contribution.

2.4. Formal definition

Consider a collaboration session interval $[t_0 - t_m]$. We quantize the time interval using a parameter n: $t_i = t_0 + i * d$, where $d = (t_m - t_0)/n$. We define the collaborative action function $CA(t_i)$ as follows:

$$\mathbf{CA(t_i)} = \sum_{k=1}^{k\max} \mathrm{Agents}(k, t_i) * \mathrm{Interactions}(k, t_i)$$

Where k values $[k{:}1(1)k_{max}]$ corresponds to the interaction channels {k=1=>chat, k=2=>sticks, etc}.

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Agents(k,t_i): computes the agents that have posted at least one message through channel k during (t_{i-1}-t_i] interval.

Interactions(k,t_i): expresses the amount of interactions that have implemented through channel k during (t_{i-1}-t_i].

Obviously, it is possible to define the per channel and/or per agent collaboration activity functions **$CA_\kappa(t_i)$** for qualitative analysis of collaboration.

2.5. Quantum sensitivity

CAF shape depends on the quantum size. Practically, it is not a problem when CAF is used after the collaboration completion since the user can select the quantum of his/her selection. During collaboration the user can select a small quantum initially, and increase it gradually with the time progress.

2.6. Implementation and interpretation

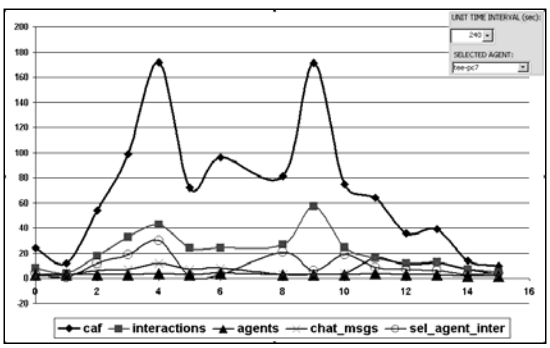

Figure 2. CAF first prototype user interface.

The first CAF prototype was developed using MS Access as a rapid development environment. Figure 2 shows the first prototype user interface and CAF for real collaboration data.

The CAF of figure 2 concerns the collaboration of three students and one teacher for about 64 minutes. The quantum duration is 240 sec= 4 min so we have 16 time slots. In figure 2 we can also see:

1. CAF's factors: *Interactions, Agents*. So it is clear if a high CAF value exists, it is because of many agents and/or many interactions.

2. The CAF for chat channel alone (*chat_msgs*). As a first collaboration quality estimation.

3. A selected agent's CAF (*sel_agent_inter*) for contribution assessment.

Observing the curves of figure 2 it is possible to formulate some interpretation rules for CAF:

R1. The more the collaborative action, the higher the CAF. If CAF is zero, no action has been noted in the corresponding time slot.

R2. CAF is always greater or equal to *Interactions*' curve. When CAF is equal to the *Interactions*' curve then there is only one active agent in the corresponding time slot.

R3. *Interactions*' curve is always grater or equal to *chat_msgs* curve. When these curves are equal then agents are just chatting in the corresponding time slot.

R4. *Interactions*' curve is always grater or equal to the *sel_agent_inter* curve. If these curves are equal then the selected agent monopolizes the action in the corresponding time slot. In general, the contribution of an agent as high as close it is its *sel_agent_inter* curve to the Interactions' curve.

Using the above rules teachers/researchers are able to observe agents groups' collaboration and get at a glance several useful information. Teachers and Researchers that were testing the CAF prototype asked for the following improvements:

1. The possibility to select any combination of agents in order to compare their contribution to the collaboration.

2. The addition of more interaction channels' curves e.g. CAF for model runs, which is a significant milestone in modeling.

3. The possibility to zoom and concentrate in selected time slots.

For the fulfillment of the above requirements an improved prototype has been developed (figure 3). In the improved CAF prototype the user can select any combination of agents in order to produce a different chart for each one or plot the curves in a common axes' system. The user can select which curves he/she wants to plot for the selected combination of agents. Finally, the user can select the time slots for which the curves will be plotted.

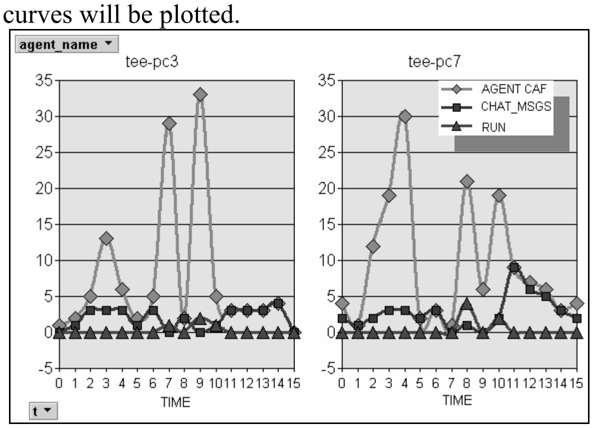

Figure 3. Improved CAF prototype in MS Access.

2.7. Possible applications

In this section a more systematic presentation of possible CAF applications is presented.

A. As a diagnostic tool for the teacher.

(1.) During the collaboration: a. Evaluation of the collaborative action of the group. **b.** Selection of time points for teacher intervention or more detailed observation. **c.** Assessment of agents' contribution to the collaborative action. (**2.) After the collaboration session: a.** Detection of critical time points for further analysis (through other analysis' tools). **b.** Collaboration quality and cognitive problems' diagnosis. **c.** Design of the next didactical activities. **d.** Students' assessment.

B. As teachers' or students' style pattern estimator: **(1.)** CAF can be used to estimate the style of teachers ('facilitator' or 'instructive') as well as the style of students (initiative-active or pathetic, collaborative or competitive). (**2.)** Furthermore, CAF can be used as a mirror in order for the agents to be aware of their collaboration style pattern.

C. Other applications: Comparison and assessment of collaborative learning tools: CAF is highly independent from its born environment (MODELLINGSPACE) and could be applied in several collaborative learning environments compatible to the general model of figure 1, for assessment and comparison.

3. Empirical evaluation of CAF

3.1 Research questions and context

The research aimed at exploring CAF's exploitation during synchronous computer mediated collaborative problem solving in real school context (on-the-fly) and afterwards (a posteriori). What is the information that they decode in order to regulate their strategies, or in order to apply new ones? How valuable does this tool appear to schoolteachers?

This unit, presents briefly a case study that took place in a real school environment, where all participants, teachers and students, were collocated in one classroom, working on different computers, with typical problem-solving activities using MODELLINGSPACE. The choice of co-located participants is justified since it has positive effects to teachers' strategies [2].

The working hypothesis underlying the research is that CAF is a helpful diagnostic tool for the teacher during collaboration (on-the-fly) and afterwards (a posteriori). The participants were four teachers (Teacher 1, Teacher 2, Teacher 3, Teacher 4), and the students of two classes of K(9) students and two other classes of K(10) students, from three different schools. Each teacher, beyond the whole class, have supervised and/or guided a specific group of two collaborating students for eight instructive hours (8 * 45 minutes).

3.2. Results' Analysis

3.2.1. How teachers used CAF. After each activity, a researcher asked each teacher to comment the CAF produced during the interaction of collaborative group supervised by the teacher. Thus, the related data are derived from the transcription of video-camera recording.

Our analysis showed that teachers used CAF for: **(a) Assessing collaboration**: *"It is obvious that Kyriakos dominated at all phases of the activity. Helen was too silent…"* Teacher 1. "*Even though students were working all alone, collaboration seems pretty good*", Teacher 4. **(b) Assessing contribution:** *"Maria did everything, Christos did nothing",* Teacher 3. **(c) Choosing the right time to intervene:** *"They are doing nothing…what's going on?"* Teacher 3. **(d) Assessing teachers' interventions**: *"I don't think I was intervening too often, especially during the phase of answering the questions",* Teacher 2. *"Well, I had a lot of action, you can see it*" Teacher 3**. (c) Choosing points that need focus, a more detailed analysis:** *"Here students got stuck as we can see, I did something and they continued*", Teacher 3.

3.2.2. Regulation of teachers' strategies. Teachers regulated their strategies according to the information they derived from CAF, doing: **(a) Self-regulation:** *"I didn't intervene too much, I want to continue like this because students must learn to work alone*", Teacher 2. *"Next time I'll try to guide them only through messages, because last time I possessed the key for too long",* Teacher 3. **(b) Planning a new group formation:** *"I have to change Kyriakos' partner, I have to find one who will be more dynamic"* Teacher 1.*"Mary and Michelle, although they were working alone, seem to have had a good collaboration, I will not make any changes*", Teacher 1.

3.3. Conclusions

The analysis showed that CAF provides teachers with some new opportunities since they can have qualitative information about the collaboration, like the degree of groups' collaborative activity, or each participant's actions including him/herself. As a result, the teacher was able to diagnose collaboration quality or cognitive problems, plan his/her interventions and assess students' contributions or his/her own interventions. CAF provides feedback about the style each teacher adapts during collaboration, for example if he/she was dominating or encouraged collaboration.

4. Teachers' points of view

During the interviews at the end of all sessions, teachers expressed their points of view about CAF. **Teacher 1** said *"I think it is a useful tool. It is very important that it contains not only quantitative but also qualitative parameters. For example, the kind of action that takes place at the shared workspace: the students are running the model, the students are inserting a relationship.* **Teacher 2** said *"I would use CAF especially if I had to observe many groups at the same time. So I would be able to find out in time that a group faces problems and is doing nothing, or that a student monopolizes the work".* **Teacher 3** said "*First of all, CAF gives me an overview of the collaboration between students but also illustrates my behavior. As far as students' collaboration is concerned, a teacher can intervene in order to help when he sees that the curve is going down. Also you can use CAF for planning the next lesson. If you repeatedly see that a group has "bad" collaboration then you must probably change the participants".* **Teacher 4** said *"CAF is giving you a general idea about the collaboration that has taken place, concerning students and teachers. I believe that if the teacher can observe students during collaboration (on-the-fly) using CAF, then he can intervene in order to make the collaboration "better".*

Teachers global point of view about CAF, points out mainly: (a) its usefulness, considering it as a tool presenting an overview, (b) its justification, showing that one can derive qualitative information, (c) teaching strategies that they can decide, based on CAF information, (d) the interest in the mode of use 'on the fly', so as to supervise many groups at the same time.

5. Discussion

This paper presented our investigation on an analysis' tool for collaborative learning environments.

CAF is an "activity-based" tool [1], [8], since it can analyze the stream of actions occurring during the collaborative work. It also enables teachers to get clues about periods of collaborative work that took place, and furthermore, it provides some kind of turn-taking analysis. Thus, CAF can support Structural Analysis, since in the activity-based dimension, this accounts for general patterns in turn-taking or division of labor [1]. CAF shows the proportional participation of each group member and can be updated on the fly for each new activity, so CAF can perform summary analysis as well, since it measures quantities or ratios of data.

Since CAF illustrates the actions of all participants, we consider that it could increases task awareness and mutual awareness. Additionally, this kind of feedback could have a major influence on motivation upon reflecting their role and try to change their behavior. Thus, it would be worthwhile, that similar information is also available to students, which constitutes one of the forthcoming steps of our present research. Another important step is to explore the appropriateness of CAF tool, during asynchronous collaboration.

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