Real-Time Collaborative Problem Solving: A Study on Alternative Coordination Mechanisms

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Abstract

It is believed that computer-supported collaboration at a distance can stimulate learning. In this paper an innovative environment that permits real-time collaborative problem solving is described. In particular we study the effect of two alternative coordination mechanisms on the problem solving activity of pairs of students engaged in concept map building. The first mechanism imposes locking of the shared activity board for one student at a time, while the second mechanism allows access of all group members to the shared activity board in a contemporary way. The reported findings are of interest to researchers and practitioners who are involved in the design and study of real-time collaborative learning environments.

1. Introduction

Late approaches in teaching and learning stress the importance of activities that involve collaboration. It seems that there is a wider acceptance of the fact that these approaches encourage construction of knowledge and building of meaning. Network-based computer systems offer new possibilities in this context and at the same time raise new questions relating to the feasibility and effectiveness of distance collaboration. For instance, special interest has been recently shown on the investigation of the conditions under which computer-supported collaborative problem solving can be effective. In this paper we study a key aspect of real-time distant collaboration-support systems: The mechanism relating with sharing of the common work surface by distant partners.

Synchronous collaborative problem-solving is often based on a shared work surface [3]. As a result communication among partners is done through the constructed artefact, found in this surface, e.g. a model under construction or the representation of a solution to a given problem. This is done in effect when one student's manipulation of the objects in this surface is observed by the other students. This indirect way of communication can be as important as direct communication [1].

Various architectural decisions are related to the design of the shared work surface. One possibility is to apply a strict WYSIWIS (what you see is what I see) approach in the main work surface window. As a result the activity in this area is faithfully reproduced in all students' workstations. So most of communication and reasoning of students is based on this shared viewpoint, which becomes the main grounding mechanism of dialogue and through which eventually common understanding can occur. However additional operations outside this shared workspace may also be performed independently by partners involved, a model-level coupling approach according to Suthers [6]. This way a more relaxed coupling of partners is achieved.

An important decision in this context is related to the floor control mechanism, i.e the coordination mechanism of the activity in the shared workspace. This can take many forms, see Dix et al [3] for a survey and a discussion of alternative approaches. Some of these approaches impose no particular control, i.e. any member has his/her own pointing device and can manipulate objects in the activity space or write on the whiteboard. This is claimed that may result in chaos with participants ending up in writing one on top of the other and cancelling each other's actions. Other approaches propose floor control mechanisms, involving the existence of a coordinator, various floor control protocols, like round-robin etc, or protocols of explicit request/ concession of the floor with time constraints. For instance inactivity of the floor owner for more than a certain time can release the floor.

The effect of the floor control mechanism in collaboration and interaction is the main focus of this paper. An innovative software environment (Modelling Space) has been used in this study. In this software we have first built a floor control mechanism while as an alternative option, we allowed no explicit control. The floor control mechanism built, involves an *Action Enabling Key*, which is owned by one of the participants at any given time. This key owner is allowed to act in the shared workspace, while the rest just observe this activity and make comments through the chat tool. This mechanism is supported by *key request* function, which can be accepted or rejected by the key owner. Through this, the floor control is passed to other participants Early experiments with this kind of floor control mechanism, see [4] and [5], have indicated that it may improve reasoning about action, as partners need to reason and negotiate during key requests. In the experiment reported here we have studied the effect of this mechanism on problem solving, by comparing the performance of two groups of students one of which used this mechanism while the other used no explicit floor control.

The software environment used in our study is *ModellingSpace* [2], a client-server distributed application, which comprises a suite of interconnected tools to support collaborative modelling activities. The typical work surface of ModellingSpace is shown in Figure 1. A peer-to-peer protocol has been used for maintenance of compatible state of the work surface in real-time, even in case of low bandwidth connections among partners. On the left-hand side column of Fig. 1 a library of entities is shown, while on the right hand-side a library of available relations (links) is included, these are the building blocks for modelling. The items included in the main window of Fig.1 (a concept map of the Internet in our example) are reproduced in all collaborating partners windows, through a replicating architecture, which allows exchange of control messages and maintains the content of the libraries in all partners sites.

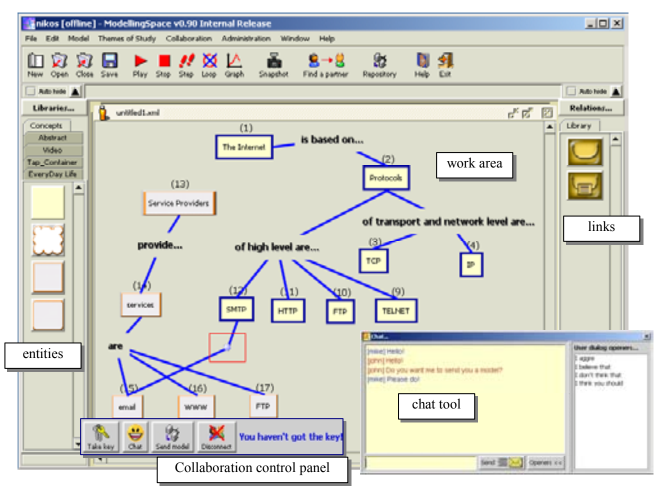


Figure 1. ModellingSpace environment

Considering that the collaborative activity is done between partners at a distance, a direct communication mechanism has also been defined. A text communication has been applied in our case, while other media, like video and audio, have been experimentally used by other researchers. In the following section the key aspects of the environment used in our study are described.

2. ModellingSpace support for communication

The main work surface of the ModellingSpace environment is shared by multiple actors, permitting collaborative modelling activities of students at a distance. Sharing this activity space, in which objects and relations can be introduced by the partners, is achieved using a peer-to-peer socket connection between two or more distance student workstations. Through these connections, the necessary control messages are exchanged, which permit the WYSIWIS shared work surface effect. This approach is preferred to a server-based architecture, since the latter would have been a bottleneck in case that many groups were simultaneously engaged in collaboration using the same server. The size of the groups engaged in synchronous collaboration is expected to be small, so point-to-point connection is feasible. The exchanged messages are of small size, as due to replication the only information exchanged relates to control of modelling activities (e.g. add entity E_i to position (x,y) of the work surface), while the entity E_i itself is not usually transferred between the distant nodes. This differs from most other shared work space environments, like *Netmeeting*, in which heavy graphical information is exchanged among partners.

It should be noticed that there are many kinds of entities in ModellingSpace. Abstract entities can be represented by textual descriptions, as in figure 1, while other entities may be represented on the work surface through multimedia files, e.g. images and video extracts. Interconnection of such entities can result in complex models.

In case that a complex entity is used by one of the collaborating partners and cannot be found in peers' workstations during modelling, a need arises to transmit this entity to collaborating peers in order to synchronize the peer applications. This may result in relatively long download times. A solution proposed for this problem is to send only light control messages directly to the peers (chat and change of state), including the structure of new primitive entities, while the multimedia files associated to these entities, if required, to be send in this case through a server to the requesting peers, without creating disruption to the rest of the group.

2.1 Direct communication

In the work surface, a text dialogue tool has been integrated, which is based on an instant messaging protocol, using the same point-to-point connection and protocol of the shared activity space. Through this, text messages are exchanged during collaborative problem solving, as shown in fig. 2.

This chat tool, which is activated from the collaboration panel, is equipped with dialogue openers, i.e. phrases like “I agree with…”, “I object to…”, “ I think that…", which can be used to open a chat message, as shown in fig.3. This way the user can select the opening phrase of the message and thus classify indirectly the speech act. There is a lot of controversy associated with structured dialogue mechanisms. Some researchers believe that they interfere with interaction and should be avoided, while others believe that they support development of meta-cognitive skills and in addition they facilitate analysis of communication and collaboration [7].

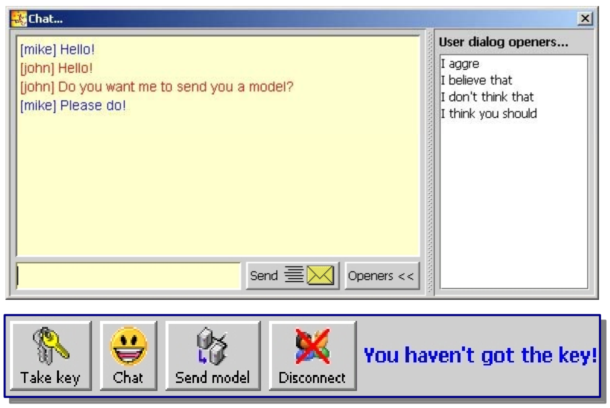


Figure 2. Chat window and collaboration panel

Other means for exchange of text messages are the sticky notes (text containers positioned in the work space), as shown in fig.3. These are treated, in terms of the architecture, as special kind of entities, with internal properties: *owner, time of creation, text_content*. Through the sticky notes, gestures can be simulated, since a sticky note inserted in the work surface, can be related to an object in this space and through this a comment by one of the partners can have a permanent effect.

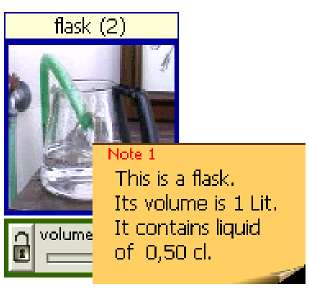


Figure 3. Use of sticky note on the work surface

3. Context of the study

The environment discussed in the previous section has been used in our case study. The experiment took place under authentic educational conditions, in the context of a first year undergraduate University course. A number of 1st year students of the *Introduction in Computer Science* course, were requested to built collaboratively models (concept maps) describing the Internet. Examples of suggested concepts were *web client, web server, browser, HTTP, Internet Service Provider, IP*, etc. The collaborative problem solving experiment took place in the frame of the class during the 2002-03 winter semester. The objective of this experiment was to evaluate the effectiveness of the architecture in supporting distance collaborative modelling activities and to examine the impact of alternative protocols of sharing the common work surface in which the concept map is built.

Thirty-two (32) students participated in the experiment in the frame of a scheduled class session. Sixteen (16) pairs of students with similar characteristics were formed. The collaborating pairs, dispersed in the computer lab, interacted for about 30', using ModellignSpace. The location of the partners was such within the class that they could interact exclusively through the provided tools, thus simulating distance problem-solving conditions. The tutor did not intervene during the problem solving process, except for facilitating use of the tools.

Each pair of students was asked to produce, by the end of the session, a single solution to the problem, using the collaborative problem-solving environment. Eight pairs of students (group A) used the key-passing floor control mechanism described in the previous section, while the other eight pairs had no explicit floor control mechanism imposed on them (group B), see Fig.4.

The two groups produced solutions of similar quality to the given problem within the allocated time. So a first observation was that the existence or lack of the floor control mechanism did not seem to affect the performance of the students.

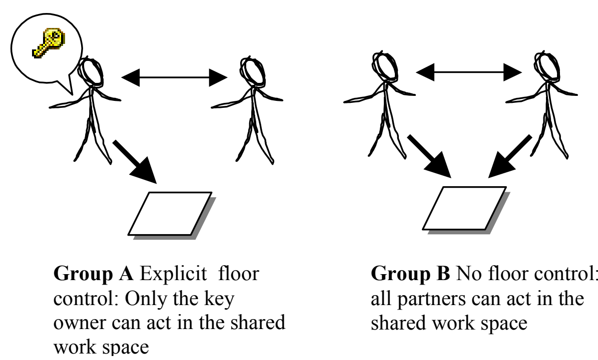


Figure 4. Setting of the case study

4. Analysis of study findings

By studying in more detail the collaboration activity through the produced logfiles and solutions, it was observed that group B was more active than group A, as shown in the chart of figure 5. The most important events (critical events) per partner of group A were in average

109, while for group B 172. The difference was found statistically significant (P=0.0131).

This observation was also valid for all major types of events (insertion of objects, deletion of objects, moving objects and exchange of chat messages). The complexity of the produced solutions by group B was also higher (it contained 27 objects against 21 in average), while this did not mean that the quality of solutions was necessarily higher.

This finding was expected, as the group with no floor control was expected to be more active since they were not impeded by explicit floor exchange and thus reacted more directly to the activity in the shared work surface.

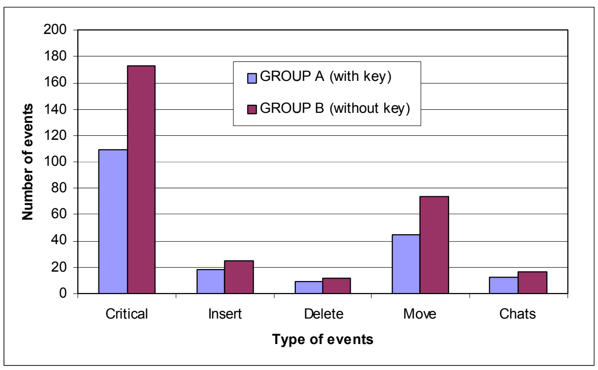


Figure 5. Events per min. of activity for groups A, B

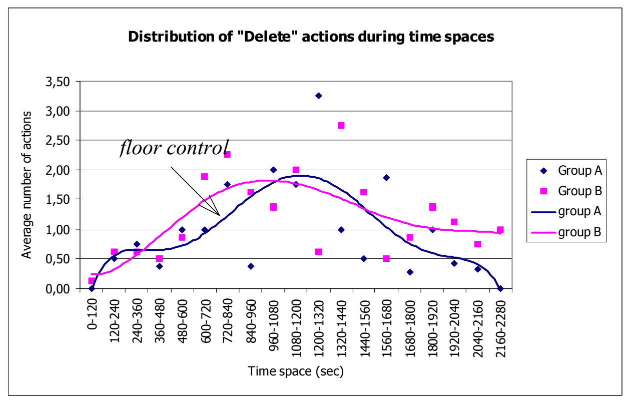
4.1 Activity evolution analysis

A more detailed analysis of the occurrence of various types of events during problem solving activity also took place. This analysis involved splitting the activity time interval in 2-min time slots and then calculating the average activity per type of event for the two groups per time slot. This way the evolution of activity per group was observed. The frequency of occurrence of events per time interval is plotted in the graphs of figure 6. The graphs of the *delete object* and *chat* events are shown in this figure. A sixth order polynomial interpolation of the points of the two groups has been included in the graphs, in order to depict more clearly the trends. From fig. 6, it is evident that the floor control mechanism that was used in the case of group B, has not affected significantly the behavioural pattern of the relevant pairs of students.

The *deletion of object* events in both groups A and B seem to follow a bell shape, i.e. with higher activity in the middle and less at the beginning and towards the end of the allocated time. A slight difference is that group B (no floor control) seem to maintain activity of this nature even towards the end of the interval, while in group A, there is a decrease of these events during the problem solving activity, since the lack of floor control permits a reactive behaviour by the partners involved throughout the activity time.

As far as the *exchanged chat messages*, it seems that group A starts with higher use of direct communication, since the floor control mechanism, obliges one of the two partners to take the passive role, and therefore use the chat tool as the sole means of expression. However later on both groups maintain similar levels of activity. What comes as a surprise is that group B maintains a good level of exchange of textual messages throughout the activity. So the partners do not seem to prefer to use direct manipulation instead of verbal expression of arguments as the problem solution is developed.

As a conclusion, the explicit coordination mechanism used in this evaluation study did not seem to inhibit the problem solving process or affect the quality of solutions. It contrary, it seems that by imposing this mechanism, the students were forced to interact more in the initial stages of problem solving while they acted less in the common activity place (group A), while the evolution of problem solving in both groups followed similar patterns.



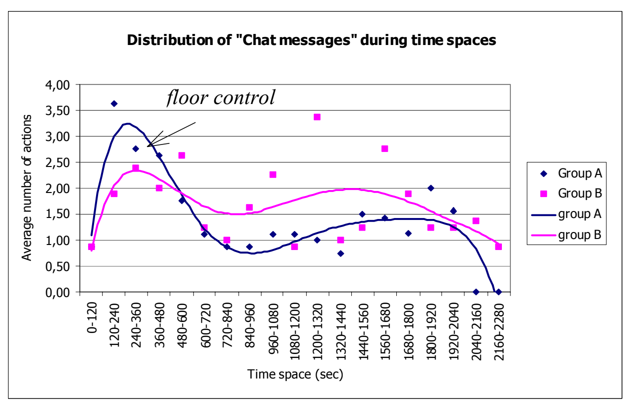


Figure 6. Evolution of frequency of events per time interval of activity (delete and chat events)

4.2 Interaction analysis

An analysis of distribution of messages to the partners of the pairs of groups A and B has also been performed. The degree of symmetry of interaction indicates the contribution of each partner to the exchanged messages. The average value of this index for group A was 0.62, while for group B was 0.42, so interaction in group A was more symmetrical among partners.

In figure 7 the symmetry of interaction of the pairs of the two groups in terms of number of exchanged messages per partner is shown in a scatter plot diagram From Fig.7 it is deduced that group A is more uniform in terms of symmetry of interaction, indicated in this diagram as closeness to the diagonal of the group interpolation line. So it seems that in the case of the explicit floor control, partners were forced to use direct communication channel in a more symmetrical way, resulting in more uniform participation in problem solving.

By performing a qualitative analysis of dialogues, it was also found that in group A students reasoned during key exchange, usually the requesting partner had to argue on the requested key in order to convince their peer. In addition, partners of group A discussed more extensively the problem-solving strategies, by allocating tasks among themselves e.g. “I will insert the concepts and while I am doing this, can you think on key relations?”. In contrary, in group B the partners seem to have a more reactive behaviour without planning the activity and taking specific roles.

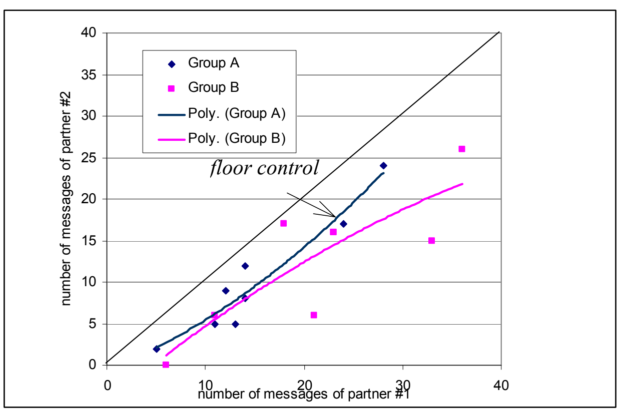


Figure 7. Symmetry of direct communication in group A (floor control) and group B (no floor control)

5. Conclusions

In this paper we outlined the main features of a new collaborative modelling environment and discussed some findings that were produced during evaluation studies under authentic learning conditions. In particular we studied the effect of two alternative floor control mechanisms on problem solving and interaction. It was found that explicit floor control of the shared work surface did not inhibit problem solving. The solutions produced by the group of students who had to use explicit floor control were of similar quality to the reference group who did not use such a mechanism. The patterns of activity where very similar in both groups. While, as expected, group B was more active than A, interaction was more symmetrical among partners in the explicit floor control group A. On the other hand it should be observed that the lack of floor control did not seem to create any confusion or conflicts to the corresponding pairs of group B. However the size of the problem-solving groups (two partners) perhaps was too small to generalise on this observation, which might not hold if groups of more students.

A more general conclusion of this study seems to be that by imposing explicit coordination mechanisms, the students have been obliged to negotiate on possession of the activity enabling key and thus argue at the meta-cognitive level of the activity and externalise their strategies, a fact that helps them deepen their collaboration, and lead to improved learning.

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7. References

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