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Agent-oriented Support Environment in Web-based Collaborative Learning[1]

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Abstract: Currently, the web-based learning support systems are one of interesting and hot topics in points of the utilization of Internet and the application of computers to education. In particular, the web-based collaboration is very applicable means to make unfamiliar students, who are unknown to each other, discuss together in the same virtual interaction space. However, there are some problems derived from the gap between the real world and virtual environment: coordination of discussions, cooperative reactions, comprehension of learning progress, etc. These problems may be dependent on the fact that the actions of students cannot be influenced from the behaviors of others directly.

In this paper, we address a coordination mechanism to promote cooperative actions/reactions for progressive discussions. Our idea is to apply an agent-oriented framework to this coordination mechanism and introduce two different types of agents. One is a coordinator and the other is a learner. The coordinator monitors the learning progress of groups and promotes the discussion, if necessary, so as to reach their common goal successfully. The learners are assigned to individual students, and act as interaction mediators among students in place of the corresponding students. Of course, the coordinator is a passive entity and learners are active entities in our collaborative learning space.

Key Words: Collaborative learning environment, coordinator, learning situation, learner, personal learning history

Category: K.3.1, K.3.2

1 Introduction

The fast and world-wide enlargement of Internet/Intranet has made it possible that every person can interact instantly without depending on their physical

[1] This is an extended version of a paper presented at the ICCE/ICCAI 2000 conference in Taipei, Taiwan. The paper has received an Outstanding Paper Award and is published in J.UCS with the permission of ICCE/ICCAI

locations. Also, various applications, which are available on the web environment, have been developed with respect to the content-based resource sharing, in addition to the traditional message exchanges. The web-based collaborative learning is one of applications, based on such a hot topic, and has been applied as computer-support for virtual learning space. If their computers were connected mutually through the web-based learning environment, students could discuss their common solving process successively and exchange various solving methods/ideas cooperatively. However, there are some problems with encouraging activated discussions among students and making it possible that individual students should understand the correct answer and solving process effectively:

1) students may not participate in the discussion interactively because of their hesitation, derived from the fact that they are unknown with each other;

2) students cannot grasp the behaviors of others directly or indirectly because only the direct actions and reactions are observable through the interactive interface.

These problems are radical drawbacks for collaborative learning.

In order to solve these drawbacks effectively, we propose an agent-oriented support environment for collaborative learning. Of course, the agent-oriented frameworks for the construction of collaborative learning mechanism/environment have been already investigated. Florea [1] proposed a multi-agent collaborative learning environment in the web world. In this environment, three kinds of agents were introduced: a personal agent which gets the information according to the requests of each student, tutor agent which generates advice when personal agents asked for the help, and information agent which acquires more information from Internet. Agents are activated by students' requests so that this system environment does not benefit passive students. Ogata, et al. [2] proposed mediator agents in the collaborative learning environment which assist students to find suitable collaborators. The mediator agent for each student holds the corresponding students' profile which indicates the understanding and interesting degrees about knowledge. When a student has problems, his/her mediator agent asks other mediator agents for the learning situations of their corresponding students and specifies appropriate students who may be able to help solving the problems. This research copes with the above problem 1) indirectly because this functionality supports the creation of appropriate learning groups, but does not manage the progress of collaborative learning. Nakamura, et al.[3] and Liming, et al.[4] introduced respectively pseudo students which correspond to individual human students. These pseudo students have the same knowledge as the corresponding students and participate into the discussion in their ways if the corresponding students do not join in the discussion positively or cannot understand the discussion stage. These research viewpoints focus on passive students such as problem

1), but do not solve the problem 2). So, in spite of these various agent-based investigations, the previous drawbacks are not always overtaken.

In this paper, we address a collaborative learning environment, organized systematically under two different types of agents: coordinator and learner. The coordinator takes roles to monitor the discussion situation among students, grasps the learning progress and guides the learning process if necessary. The learners are virtual students corresponding possibly to individual students in our web-based collaborative learning environment. The coordinator and learner are complementary entities in the learning environment: the coordinator is a passive entity; and the learner is an active entity as the autonomy for practically participating students. In our investigation, we expect the collaborative learning of high school students who study mathematical exercises together, especially computation for the roots of equations. First of all, we show an overall framework of our collaborative learning environment on the web-world in Section 2. The functionalities of two different types of agents are stated in Sections 3 and 4, and then our prototype system is shown in Section 5. Finally, we conclude our paper in Section 6.

2 Collaborative Learning Environment

In the web-based collaborative learning environment, the actions/reactions of participating students are inherently different from their behavior in the real world. Students in the physically constrained learning space can speak with each other by means of face-to-face, feel/recognize activities, occurring from the discussions of students, directly by various sensitive receptors and find out some new events/facts indirectly. Although these are not always implemented adaptively in the web-based virtual learning space, it is necessary to organize a collaborative learning environment in which the logical activities for support of interaction, discussion and comprehension can be implemented successfully and effectively.

Figure 1 shows our collaborative learning environment conceptually, which is characterized by two different types of agents: coordinator and learner. The coordinator is placed in the center of our virtual classroom (as a network server), monitors the interaction among students and generates advice if necessary, according to the learning situation. This interaction is supported by the conversation means through the public communication line. The learner is a pseudo student in our virtual classroom and is assigned to the corresponding student one by one. The learner takes roles of the personal management of interaction interface for the corresponding student, the handshaking control of public communication line, the management of its own private learning history, and so on. In addition, the learner can communicate with other learners directly through the private talking line in order to exchange their personal learning histories.

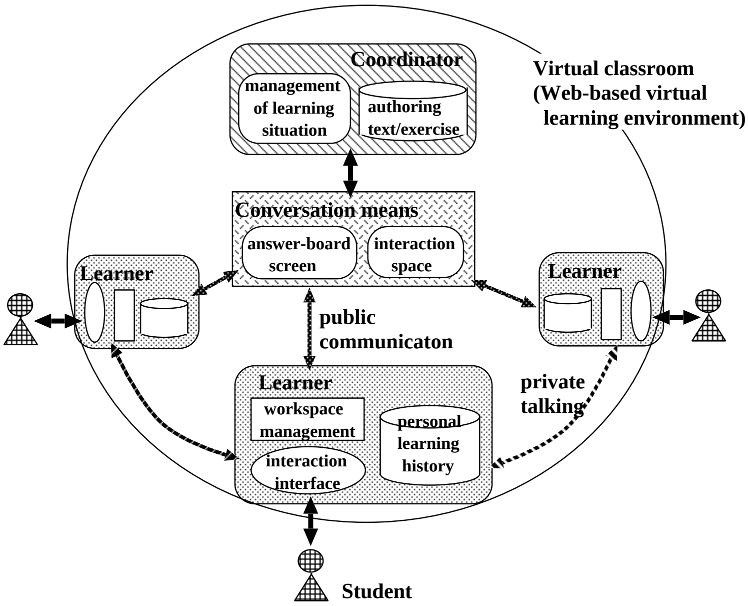

Figure 1: Collaborative learning environment

Since students are studying with limited learning tools in the web-based virtual learning space, they are sometimes not able to communicate naturally. Furthermore, various students participate in the learning group and the learning process is not always completed successfully: i.e. some students are not able to solve the problem, some students are not able to understand the derived answering process after all, and so on. The coordinator solves such drawbacks in the web-based virtual learning space by managing the learning situation globally: the coordinator takes the place of a teacher in our classroom activity. For the purpose of resolving inappropriate learning situation stepwisely and guiding the learning group effectively, how to model and control learning situation is an important subject. If the coordinator grasps the learning situation appropriately, the advice which were generated may become appropriate hints in order for the learning group to proceed to the next phase of learning process. However, it is not always necessary to model the learning situation in detail precisely. This is, we think, because among the learning group students are able to help each other by discussion, so that the coordinator only has to detect the situation in which the learning group cannot proceed the learning by itself.

The coordinator holds the right answer and the answering paths for an exercise as knowledge to grasp the current learning situation. When the exercise

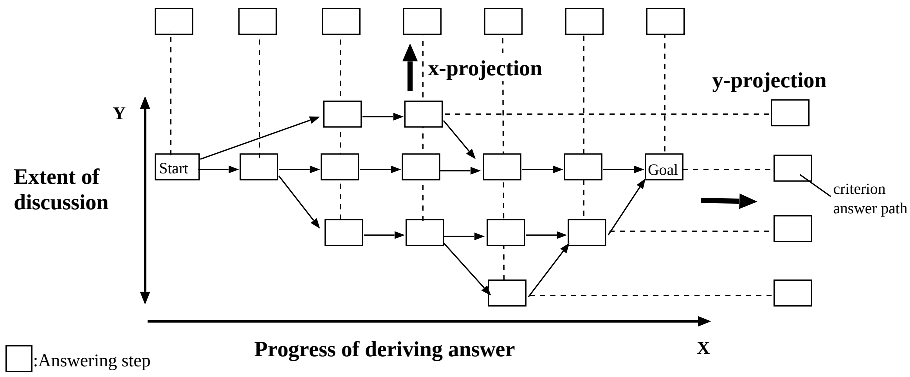

Figure 2: Answer space

has several answering paths for the goal, the answer space of the exercise is expanded as 2-dimensional network structure as illustrated in Figure 2. In this figure, the learning progress along x-axis means the stepwise progress of deriving answer, whereas that along y-axis shows the extent of discussion. If the coordinator grasps the learning situation on the basis of the answering process of network structure as it were, it is very troublesome to manage the eventually changeable conversation stages successively. Therefore, our coordinator manages the learning situation with respect to the following two viewpoints separately: ratio of derived steps for a whole answering process and extent of discussion. By monitoring the learning situation under these points of view, the coordinator is able to grasp the learning situation easier and generate advice timely. In particular, it is necessary and sufficient to manage the learning situation of the group globally, and not individually of each student.

The learner acts as a network client in place of the corresponding human student in the web-based virtual learning space. This provides not only the interaction interface for virtual learning space attached to the corresponding student, but also the function of indirect interaction among students, so as to judge their understanding levels or personalities, which we call the focus function. According to the focus function, students select the opinions of particular students whom they evaluate as key persons. In order to realize the focus function, the learner needs to have the knowledge about the corresponding student and exchange it with other learners. Therefore, the personal learning history is prepared for the learner, which represents the understanding level and personality of corresponding student. The learner constructs and maintains the personal learning history according to the current situation. Exchange of personal learning

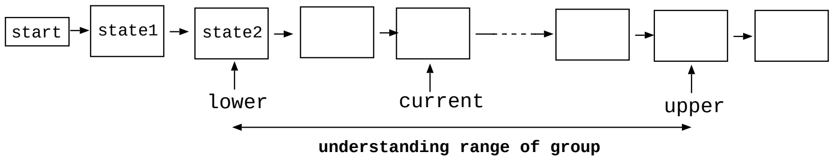

Figure 3: Resolution derivation scenario and indicators

history is one-to-one interaction so that public communication is not necessary for the focus function. Therefore, we introduce the mobile agents called mediators as children of the learner who take responsibilities for the exchange of personal learning histories among learners. The mediator moves among learners by requesting/carrying the personal learning history on the private talking line.

3 Coordinator

The coordinator grasps the learning situation from two viewpoints: ratio of derived steps for a whole answering process and extent of discussion. For the ratio of derived steps, which corresponds to the x-axis of answer space in Figure 2, we have already proposed the resolution derivation scenario which represents the phases of deriving answer stepwisely [5, 6, 7]. The scenario is generated by means of projecting the answer space onto x-axis and consists of ordered states which correspond to individual phases of deriving answer. Grasping an approximate learning situation makes it possible for the coordinator to generate advice timely and effectively because each state corresponds to the individual ratio of derived step. In our scenario structure, the current learning state is pointed by the indicator *current*, which points out the currently discussing stage. The coordinator infers the current state from student inputs and moves the indicator to the corresponding state. However, the utilization of only one current discussion indicator is not enough to manage the learning state of a group sufficiently. In addition to *current*, indicators *upper* and *lower* are prepared for the representation of current understanding levels of a learning group. *Upper* points out the state of understanding level which is estimated that best understanding student reached to and *lower* points out the state of worst understanding student. The coordinator is able to grasp the learning situation on the basis of the relationship among these 3 indicators (Figure 3).

On the other hand, the extent of discussion is estimated by the number of derived answering paths with different discussion viewpoints. The difference of discussion viewpoints among answering paths is defined as the ratio between common and uncommon answering steps. That is, if two answering paths contain large number of answering steps as common part, they are regarded as more similar paths; but if they have many different answering steps, they are judged as different paths. Common answering steps mean that the answering methods which are used to derive those steps are the same. Once two answering paths were diverged, the following answering steps may be derived based on different answering methods so that they are regarded as being uncommon. From such viewpoint, the coordinator holds an answer tree which was transformed from the whole answering paths as a tree structure. Figure 4 shows the construction of an answer tree, derived from the answer space in Figure 2. The answering steps after the divergence are regarded as uncommon steps so that they are copied as different objects (Figure 4a). Then, the answer tree is transformed by means of collecting common answering steps for the purpose of grasping the difference among the answering paths. The nodes in the tree are generated as a collection of answering steps that are common to particular answering paths and the path from root node to particular leaf node corresponds to each answering path. When the answer has been derived, the coordinator specifies derived/underived answering paths, calculates the differences between the derived answering path and other answering paths based on the answer tree, and estimates the extent of discussion.

By grasping the learning situation from these aspects, the coordinator is able to handle the changeable learning situation and generate appropriate advice at the right time.

4 Learner

The learner is situated on each student's computer and acts as a pseudo student in the web-based virtual learning environment. The learner provides the interface to the human student and controls the private talking among students such as focus function. Since the learner only connects the private talking line according to the corresponding student's request, it behaves independently with the coordinator that manages the public communication.

A personal learning history is the model of corresponding student which is held by the learner. The personal learning history represents the understanding level and the characteristic of corresponding student. Some data of personal learning history are prepared by the human student beforehand and others are gathered by the learner occasionally through the learning. Currently, the picture and utterances of students are collected as a personal learning history. The features of students do not change through the learning, so the picture is set by each student before the learning starts. Utterances indicate the understanding level of students and also their attitudes toward the learning; i.e. active or passive,

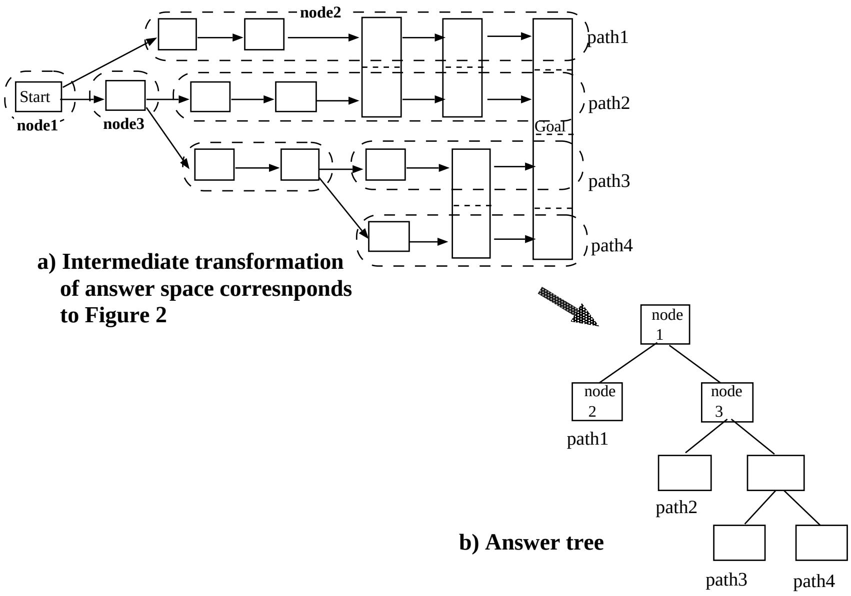

Figure 4: Construction of answer tree

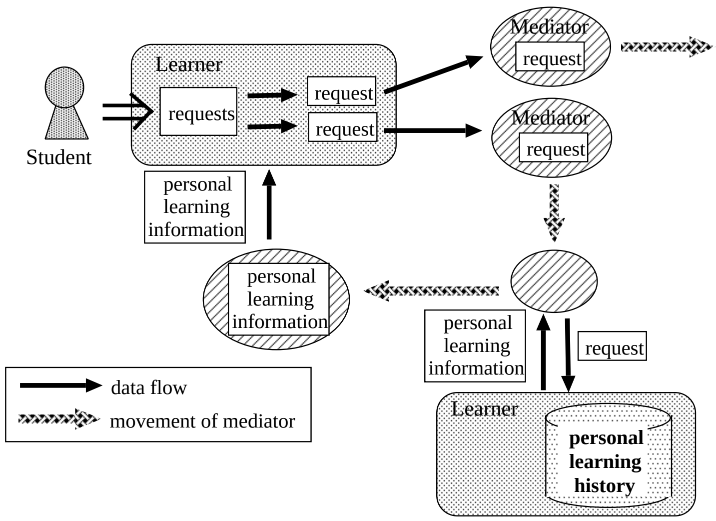

Figure 5: Mechanism for acquiring personal learning information

understanding or not-understanding, and so on. They are gathered and added to the personal learning history by the learner when the corresponding students send their opinions to the public communication line.

In order to exchange the personal learning history through private talking line, the learner generates mediators for each communication. The mediator is constructed as a mobile agent which processes its task while moving through the network autonomously [8]. Figure 5 shows the movement of mediator for acquiring the personal learning history of other students. When the corresponding student requests to get the personal learning histories of particular students, the mediators are generated by the learner respectively. Once generated, the mediators move to the target learners through the network and ask for the personal learning histories, attended inherently to the target learners. After the acquisition of personal learning histories, the mediators move back to their original learner and disappear autonomously, since their roles are to acquire the personal learning histories from target learners. Under such mechanism, students are able to know other students' characteristics even in our web-based virtual learning environment without any direct interaction.

5 Implementation

We have implemented our prototype system on Internet using UDP protocol, since UDP protocol is suitable to control the frequent interaction of short messages. Figure 6 shows the interaction interface in our system. Two communication tools are prepared: answer-board screen and interaction space. The answer-board screen is a public communication tool which is used to arrange the group's answering process. Only one student is permitted to input on the answer-board screen at a time so that the input right is set. On the answer-board screen, ID, student's name, and contents of input are shown. The answer-board screen functions as a blackboard in our real world. Descriptions on the answer-board screen can be erased or modified, but once they are overwritten, you cannot see them again. On the other hand, the interaction space is prepared for free conversation so that all students are able to input freely. In order for the coordinator of our system to grasp the learning situation easily, commands that classify the opinions are introduced: Appreciate, Inquire, Assert, and Confirm. Students choose the commands when they input their opinions. In addition to the commands, students specify the target inputs which trigger off their opinions for the purpose of grasping the flow of conversation smoothly. Thus, in addition to the ID, student's name, and contents of input, command and ID of target input are also displayed on interaction space.

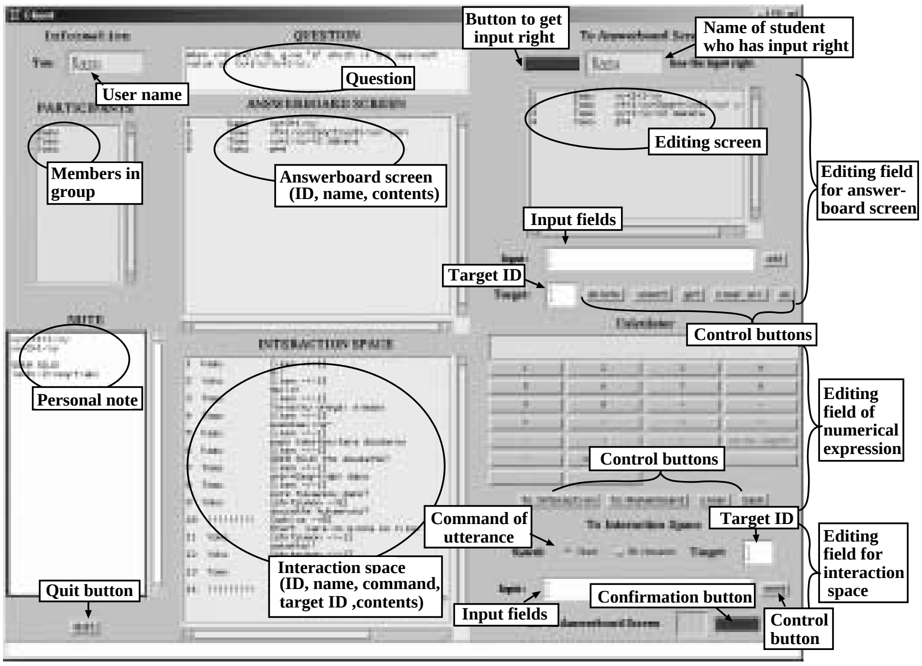

Figure 6: Interaction interface on student operation

5.1 Coordinator

As for the coordinator, we prepared several advice which indicate the states of learning situation when the learning proceeds inappropriately. Currently, the coordinator generates advice when it detects the following learning situation:

- learning situation has not been changed for a long time,
- some students cannot understand the currently discussed stage, and
- students have not derived all viewpoints of solving the exercise.

The coordinator's objective is to activate the discussion, so the advice is generated on the interaction space as the same style as all other students' utterances. Figure 7 shows an example of advice generated by the coordinator. As for the advice, the speaker's name is set as "!!!!!", the command of advice is "advice", and the ID of target input is nothing because the advice is generated for the learning group but not for individual students.

We have evaluated the generated advice based on this coordinator mechanism. We made 5 groups of 2 to 6 students, who use the prototype system, to

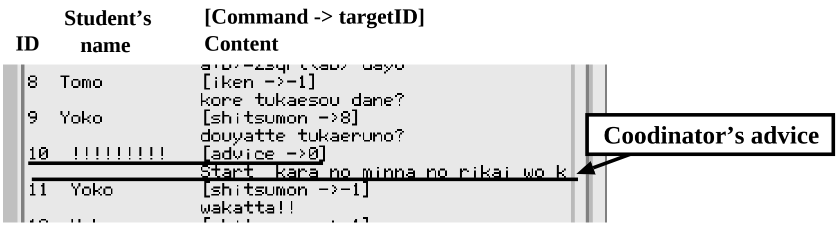

Figure 7: Advice example of coordinator on interaction space

Table 1: Impression and understanding of the exercise

What is your impression of the exercise?		
	Group with coordinator	Group without coordinator
difficult	2	1
rather difficult	5	1
appropriate	0	0
rather easy	2	2
easy	1	2

Can you understand the exercise?		
	Group with coordinator	Group without coordinator
yes	5	1
so-so	3	4
no	0	1
others	2	0

solve a mathematical exercise. These groups were divided into two groups; one used the prototype system which contained the coordinator mechanism and another studied with the same interface but without the support of a coordinator. The groups were selected randomly. After the learning, we asked about the impression and the understanding of the exercise (Table 1). For the group with the coordinator, 80% students understood the exercise after all in spite of the number of students who thought that the exercise was to some extent difficult. Furthermore, no student was not able to understand the exercise, while one student could not comprehend in the group without the coordinator. On the other hand, Table 2 shows the results of the questions about the advice generated by the coordinator and the questions asked by the students who participated in the group with the coordinator. Most students who answered that the advice are inappropriate for both questions answered that the exercise is easy in Table 1. Therefore, the coordinator may detect inappropriate learning situation precisely and promote understanding of students toward the exercise, especially of those who did not understand well and really needed effective advice.

Table 2: Advice of the coordinator

	Timing of advice	Content of advice
appropriate	0	3
mostly appropriate	5	3
not so appropriate	1	1
not appropriate	3	1
others	1	2

5.2 Learner

The learners were implemented using AgentSpace[9] as a middle-ware to control the behavior of a mediator. Figure 8(a) is an interface for generating requests. In the upper window, the causality of utterances on interaction space is arranged based on corresponding student's utterances. The arrangement of utterances on the upper window helps to decide the focusing students for generating requests. Once a student decides to focus students, he/she inputs IP addresses of focusing students, because mediators need IP addresses where they will work beforehand in our current version. Then, he/she specifies the file name of a focusing student's personal learning history. If a student wants to know only the particular utterances of focusing students, he/she sets the ID's of corresponding utterances shown in the upper window. Figure 8(b) shows the result windows of requests for personal learning history. When requests have been completed successfully, the result windows are generated and the personal learning histories of focusing students are shown individually. Currently, the picture of a focusing student is shown in the upper window and his/her utterances are shown in the lower window.

6 Conclusion

In this paper, we proposed a collaborative learning environment which contains two different agents: coordinator and learner. The coordinator monitors

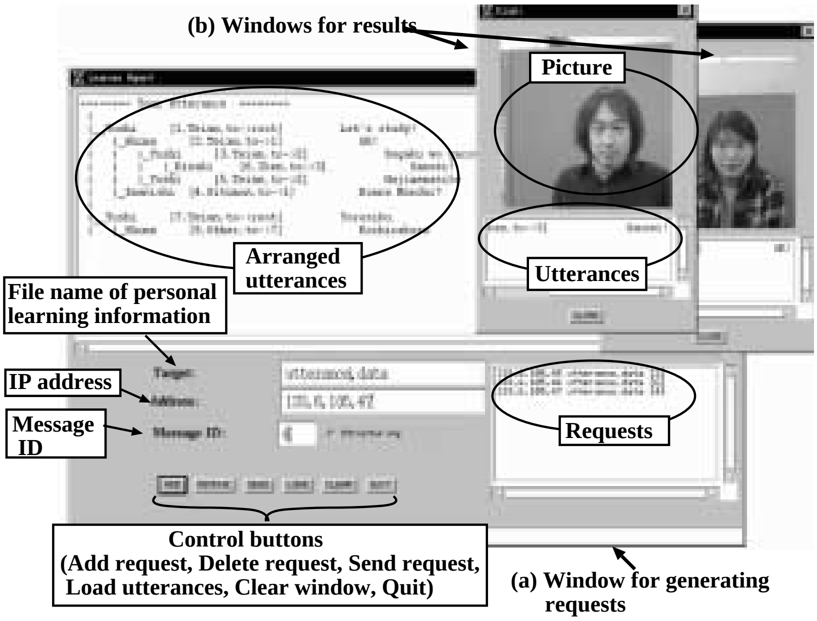

Figure 8: Interface for handling requests

the public communication among learning groups and generates advice so as to lead the groups to their learning goal. For this purpose, the coordinator grasps the learning situation globally from two viewpoints: the ratio of derived steps for a whole answering process and the extent of the discussion. Although the management structure of the learning situation is simple, the coordinator may be able to find that in most cases students are not able to cope with inappropriate learning situation by themselves. On the other hand, the learner controls the private talking such as focus function. The learner holds the personal learning history of the corresponding student as his/her characteristics and acquires other students' personal learning histories by generating the mobile agents called mediators. Currently, these agents function independently. However, for our future work, the interactions among coordinator and learners are necessary for the coordinator to generate more effective advice. In addition, the evaluation of the interaction interface of our prototype system and the preparation of more factors for personal learning history based on the result of the evaluation are also necessary.

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References

1. A. M. Florea: "An Agent-based Collaborative Learning", *Proc. of ICCE'99*, Vol. 1, pp. 161–164 (1999).
2. H. Ogata, K. Imai, K. Matsuura and Y. Yano: "Knowledge Awareness Map for Open-ended and Collaborative Learning on World Wide Web", *Proc. of ICCE'99*, Vol. 1, pp. 319–326 (1999).
3. M. Nakamura and S. Otsuki: "Group Learning Environment Based on Hypothesis Generation and Inference Externalization", *Proc. of ICCE'98*, Vol. 2, pp. 535–538 (1998).
4. G. Liming, H. Minghua and Q. Yuhui: "A Web-based Multi-Agent Collaboration Learning System", *Proc. of ICCE'98*, Vol. 1, pp. 205–210 (1998).
5. T. Kojiri and T. Watanabe: "Cooperative Learning Support Mechanism, Based on Scenario of Specifying Solving Process", *Proc. of ICCE'98*, Vol. 2, pp. 532–534 (1998).
6. T. Kojiri and T. Watanabe: "Adaptable Learning Environment for Supporting a Group of Unspecified Participants in Web", *Proc. of SITE'99*, pp. 1937–1942 (1999).
7. T. Kojiri and T. Watanabe: "A Management Method of Leaning Situation in Collaborative Learning", *Proc. of ICCE'99*, Vol. 1, pp. 386–393 (1999).
8. J. E. White: "Telescript Technology: Mobile Agents", *Software Agents (J. Bradshaw (ed.)), MIT Press*, pp. 437–472 (1997).
9. I. Sato: "AgentSpace", *http://islab.is.ocha.ac.jp/agent/* (1999).