INTEGRATED SUPPORT FOR HUMANS AND ENVIRONMENTS IN TODAY'S KNOWLEDGE-BASED SOCIETY

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ABSTRACT

The objective of our research is to construct a knowledge infrastructure environment and support intelligent human activity in today's knowledge-based society. We focus on humans and their environment, and provide support functions for human activities from viewpoints of communication among humans, interaction between humans and environment, and the events and objects in environment. This paper introduces conceptual idea of supporting the knowledge-based society. As one of support function for communication among humans, we have developed a collaborative learning support environment called HARMONY. To support the collaborative learning activities of multiple students, behavior-sharing and environment-sharing are essential to promote their intentions for coordinating with other students. To achieve this goal, HARMONY includes a mechanism for generating advisory diagrams as a form of behavior-sharing, and an operational interface that provides information based on students' preferences as a form of environment-sharing.

1. INTRODUCTION

Our society in the 21st century is often called the "knowledge-based society," the social impact of which is not dependent on industrial products but is derived predominantly from knowledge itself. Namely, what is valuable viewpoint is the actual knowledge more so than the industrial products generated from that knowledge. In this knowledge-based society, the schema and principles of our social system and social structure have drastically shifted toward the concept of "logical functions/mechanisms" from the concept of "physical functions/mechanisms." Our research focuses on knowledge technologies for constructing a knowledge infrastructure environment and supporting intelligent human activities.

Our research deals with the knowledge-based society from the viewpoints of communication among humans, interaction between humans, and events and objects in their environment, and analysis of environment. Based on these viewpoints, our research schema is categorized into *knowledge/data engineering* (KE), *parallel/distributed process environments* (PD), and *recognition/understanding systems* (RU). Figure 1 illustrates the positions of the research categories in the knowledge-based society. KE supports interaction or collaborative activity among humans by providing user-oriented virtual working environments. The research targets are modeling methods of human preferences and supporting functions that provide effective information based on the models. PD plays a role of bridging environments and humans. This assists human activities by providing effective environments for them. Such research makes use of current information technology, including ad-hoc networks or parallel processing to enhance the effectiveness of learning by humans. RU analyzes the situation in the environment so as to support the activities of humans in that environment. This research focuses on grasping the characteristics of objects and events in the environment by recognizing data acquired by various sensors.

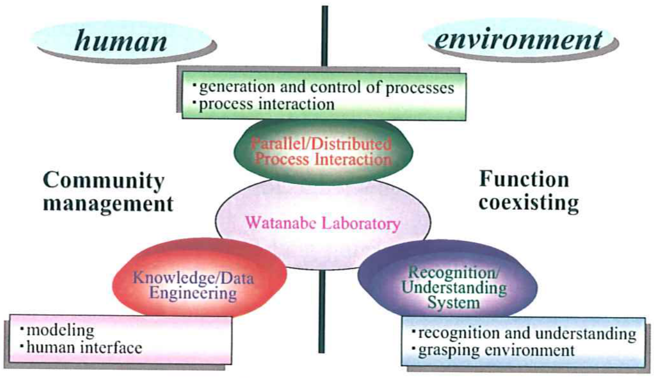

Figure 1: Research viewpoints

Many research topics in our laboratory fall within the scope of this the viewpoints expressed above. In this paper, we introduce one of our research topics in the field of KE, which supports humans' learning activities as a group, named HARMONY. HARMONY focuses on collaborative learning activities in which multiple students share a common learning goal and accomplish the goal collaboratively through discussions [1, 2]. HARMONY promotes students' knowledge-acquisition processes by monitoring the shared space in a virtual learning environment. In the remainder of this paper, we describe the overall framework of HARMONY and its mechanisms.

2. OUTLINE OF HARMONY

In collaborative learning, since students do not share the same physical space, they sometimes cannot communicate smoothly nor acquire knowledge effectively. Watanabe insisted that environment-sharing and behavior-sharing are important for collaborating efficiently with others [3]. Environment-sharing corresponds to students' feelings about sharing a physical environment and communicating with others naturally using the five senses. On the other hand, behavior-sharing indicates students' consciousness about tackling common learning activities. Behavior-sharing can be divided into several cognitive levels such as knowledge, context, and process. To realize such environment-sharing and behavior-sharing is essential for accomplishing effective and efficient collaborative learning in a virtual learning environment.

In HARMONY, two support mechanisms are introduced to assist behavior-sharing and environment-sharing, respectively. Figure 2 shows the conceptual image of HARMONY.

➢ Behavior-sharing support

In collaborative learning, it is important for multiple students to cope with exercises in a common learning context. However, since the level of understanding among students may differ, it sometimes happens that they cannot contribute to a discussion. In HARMONY, for the purpose of coordinating learning activities of individual students, we introduce the coordinator agent, which monitors the discussion and grasps the learning situation. The coordinator agent's objective is to ensure that all students acquire the necessary knowledge for the exercises through discussions. Therefore, it must grasp the group's learning process to attain their learning goal from interaction among students and generates advice if necessary. To promote active discussions among students, the advice should not force them to derive an answer via a specific answering method; instead, advice is needed that leads them to consider the most appropriate answering method by themselves.

To date we have focused on the collaborative learning of high school mathematics. In mathematics, diagrams are used to represent a conceptual image in a learning situation [4]. In other words, students can understand the concept of learning situations visually through diagrams. In a diagram, figures corresponding to derived equations and other particular figures are added to the primary diagram when applying an answering method or formula. In our research, we introduce a mechanism that generates supplementary figures automatically which assists to derive the next answering step. Since it is difficult to prepare supplementary figures for all answering steps, supplementary figures that correspond to formulas or answering methods are described as rules for applying figures to the current diagram. The rules are then selected on the basis of forward reasoning. Although all answering methods whose conditions satisfy the current diagram can be selected even if they are not appropriate for the target exercise, students can consider not only the correctness of indicated answering methods but also that of the proposed supplementary figures.

➢ Environment-sharing support

One of the characteristics of interaction in physical space is that we can use the five senses to acquire relevant information effectively without making any extra effort. For example, by using the sense of sight we can focus on something unconsciously and acquire detailed information by focusing sharply on the target. By introducing our interaction function to the virtual leaning environment, students can feel like they are sharing the same physical learning environment with others.

To generate an environment resembling the real world, we need to construct a user-oriented interface that behaves like the sense of sight, possessing a focusing function for students. That is, the interface grasps the preferences or characteristics of individual students, determines the information that they require, and provides it automatically. If the interface can provide appropriate information to students, they are able to acquire meaningful information efficiently and easily, and their learning may proceed smoothly.

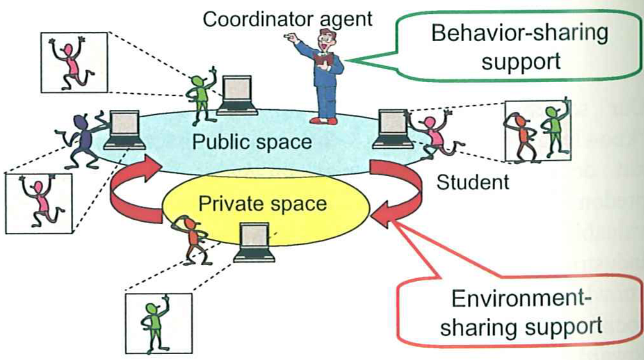

Figure 2: Conceptual imagination of HARMONY

3. BEHAVIOR-SHARING SUPPORT OF HARMONY

The coordinator's task is to generate advice when a group's learning cannot proceed smoothly. Such advice should stimulate discussion about various answering methods related to the exercise. In mathematics, an appropriate formula or answering method whose conditions satisfy the current diagram is selected and applied to that diagram. Thus, to compare various formulas based on the current diagram and consider whether they are appropriate for the answering paths is an important learning process. For the purpose, the coordinator generates supplementary figures based on the current diagram in order to promote vigorous discussion about various formulas.

The difference between diagrams can be defined from various viewpoints. If we look upon a diagram as a collection of figures, the number of existing figures and their types should be examined. However, if we regard a diagram as a mapping of equations in two-dimensional space, coordinates that figures take need to be compared. In collaborative learning, it is worthwhile for groups to discuss various answering paths. When answering paths are different, the existing figures and their relations are different because figures correspond to equations. Therefore, an inner model of a diagram is introduced that represents figures and their relations in predicate form [5, 6]. To represent meaningful figures in the functional domain, six predicates are introduced, including the x- and y-axes. In addition, twelve types of meaningful relations are also prepared. These relations are useful for discriminating the conditions of answering formulas.

Rules for drawing diagrams are defined for individual formulas or answering methods [5, 6]. They specify supplementary figures that are hints for deriving the formulas. Since conditions for applying formulas are defined according to the characteristics of derived equations, rules for drawing diagrams are described by using predicates prepared for the inner model: namely, figures and their relations. Regarding the conditional parts of rules, figures and their relations are defined that indicate the conditions for applying the corresponding rules. As for the action part, there are explanations for adding supplementary figures and their relations with the existing figures. Currently, two types of figures are prepared in each formula: one is to emphasize figures in the conditional part; the other is to display figures that should be derived through applying the formula. The following is an example of rules for drawing a figure, which corresponds to the answering method of generating a tangential line that runs parallel to the existing line. By this example, when a parabola and a line that are not in contact with each other exist, a tangential line that is parallel to the existing one is added.

$$\textit{IF}\ \exists x, y\ [(PARABOLA(x) \wedge LINE(y) \wedge \neg CONTACT(y,x)]$$
$$\textit{THEN}(add(LINE(z), PARALLEL(y,z), CONTACT(x, z)))$$

When an impasse situation is detected, one rule whose conditional part satisfies a current diagram is selected and applied to the current diagram. If conditional parts in multiple rules are applicable to the current diagram, the rule whose conditional parts include the most predicates is chosen.

Figure 3 shows the interface prepared for drawing a diagram. In this case, a student has two canvases for drawing the diagram. One is a private canvas for a student and the other is a public canvas for a group. Only one student can draw at a time on the public canvas, so the button to get the drawing turn is prepared. To draw the diagram, students push buttons representing figures and relations, and click the coordinates in the canvas. This interface is also equipped with a chat function to enable free discussion.

In the current version of the interface, supplementary figures are generated when the help button is pushed, after which rules for drawing diagrams are applied and supplementary figures are added to the public canvas automatically. Supplementarily added figures are different from other figures with respect to color in order to highlight them. Figure 4 shows an example of supplementary figures generated in the interface. In this example, a line that connects the existing point and line is generated to indicate the formula for deriving the distance between the point and the line.

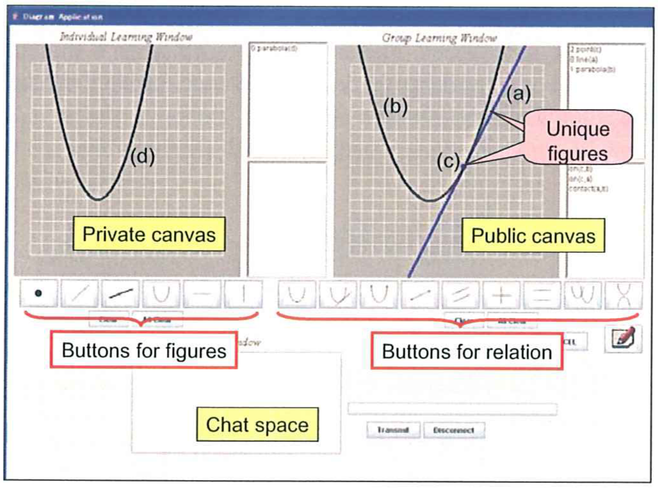

Figure 3: Interface for drawing diagrams

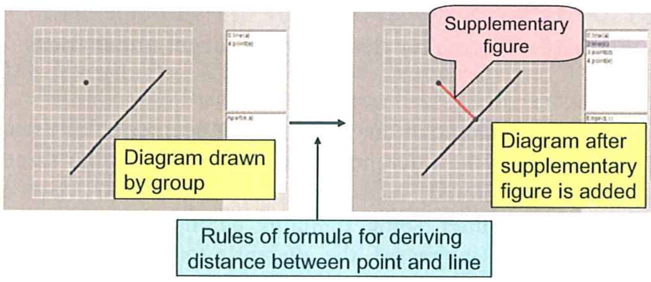

Figure 4: Example of generating supplementary figure

4. ENVIRONMENT-SHARING SUPPORT OF HARMONY

During the discussion, we do not see all students at all times; sometimes we observe the speaker to grasp his intention, or focus on other specific student to see her reaction. If the interface grasps the target of the student's focus and provides his information automatically, students do not have to expend extra effort to operate the learning environment. For this purpose, we have developed a user-oriented interface that determines the target student on whom the corresponding student wants to focus and displays the face of target student by acquiring the image from his network camera.

During the discussion, students judge other students according to their utterances. Based on the analysis, we found out that students tend to be interested in the student who is the target of the utterance if students are speakers; otherwise, students focus on the speaker if they themselves are targets of the utterance [7]. When students are not directly related to the utterance, whether students are focused on and whom they want to see depend on the topic of the utterance. That is, if students are interested in the topics, they may be conscious of the student who is speaking or who can provide a good response to the utterance. Figure 5 shows the process for determining which student is under focus. The target is decided when a student is a target or a speaker of a certain utterance, or is interested in the topic of the utterance.

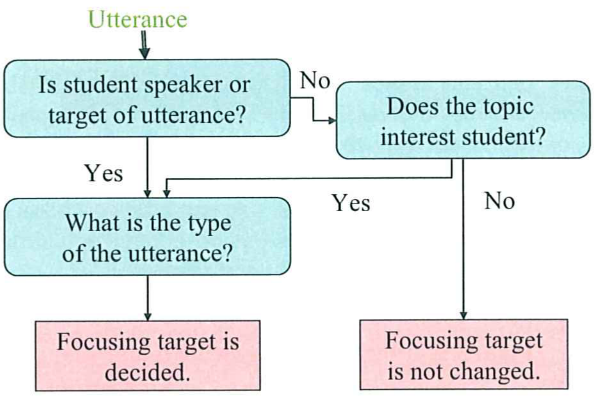

Figure 5: Process for detecting the target under focus

To grasp the topic of the utterance, the learner holds topic trees in which the utterances that are related to the same topic are structured, based on their contexts [7]. Since students may utter some opinions against the topics in which they are interested, the student's topic of interest is grasped by counting the number of utterances the student makes about each topic. If that number exceeds the specified threshold, the topic is regarded as his topic of interest.

When the utterance satisfies the conditions for deciding the target, the target on whom the student focuses is detected using the focusing rule. Our focusing rule represents the ratio of the change in the student's interest toward other students according to their individual utterances. Table 1 shows an example of focusing rules. In this example, a group of four students are estimated so that the ratios of changing interest for individual rules are set for all students except student himself, i.e. students A, B, and C.

Table 1: Example of focusing rule

Speaker and target student: Type of utterance	Ratio of degree of interest
Student A -> all: Appreciate	Student A: 0.6 Student B: 0.2 Student C: 0.2
I -> Student B: Inquire	Student A: 0.0 Student B: 1.0 Student C: 0.0

When the utterances are input to the interface, the focusing rule that corresponds to the utterance is extracted and the interest values for each student are calculated. Equation (1) is the calculation method, where $V(u,t)$ indicates an interest value in student u at time t, $P(u)$ represents the ratio of the degree of interest in student u defined in the focusing rule, U means all students, and a is a weight value reflecting a focusing rule. According to Equation (1), the ratio of the degree of interest in the focusing rule is added to the current interest value with the weight value a, and all the interest values for all students are regulated to 1. The current target of focus is regarded as the student who gains the most interest from other students.

$$V(u,t+1)=\frac{a\times P(u)+(1-a)\times V(u,t)}{\sum_{u'\in U}\{a\times P(u')+(1-a)\times V(u',t)\}} \quad \dots (1)$$

We have constructed a prototype system to automatically acquire camera images of the student's current target under focus. If the target under focus is changed, the camera image provided to the student also changes. Figure 6 shows the prototype system's interface. In this system, students have to use the chat window to communicate with other students. To grasp the types and targets of utterances more easily, students have to input such information when generating utterances. The camera image of the target under focus is provided in a different window. By automatically displaying the camera image of the appropriate student, other students do not have to expend any extra effort to acquire the information of the target under focus, and can instead do so naturally. In addition, because students' operations for acquiring the information are reduced, they are able to concentrate on learning and gain knowledge more efficiently.

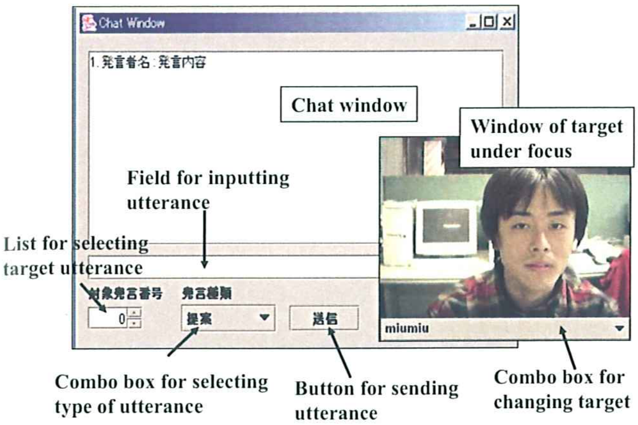

Figure 6: Interface for providing face image of target under focus

In this interface, student can also acquire camera images of individual students by themselves. If the camera image provided by the system is changed by the student, it means that the system could not determine the target under focusing correctly. Therefore, the ratio of the degree of interest on the in the focusing rule that was applied most recently should also be changed. Equations (2) and (3) represent processes for calculating the ratio of the degree of interest in the focusing rule. Equation (2) is a calculation for student u, who is requested by the student. Equation (3) is for student u', who is not requested, and $P(u)$ is the ratio of the degree of interest for student u in our focusing rule. Furthermore, N denotes the total number of students and b is a weight for updating the focusing rule. By calculating the ratio of the degree of interest according to the students' actions, the student's tendency to focus on other students can be modified and an appropriate student is displayed as a target under focusing.

$$P'(u) = P(u) + \frac{b}{N-1} \qquad \ldots(2)$$

$$P'(u') = \frac{P(u')}{\sum_{u'' \in U, u'' \neq u'} P(u'')} \times (1 - P'(u)) \qquad \ldots(3)$$

5. CONCLUSION

In this paper, we introduced a model for supporting knowledge-based society from the viewpoints of communication among humans, interaction between humans and their environment, and events and objects in environment. Currently, research in each category is being carried out separately, and we have not adequately discussed the relations among these research categories. Therefore, to accurately evaluate our model for supporting knowledge-based society, it is important to conduct researches for supporting common human activities in each of these three categories and to develop a system that integrates them.

In this paper we explained the collaborative-learning support environment HARMONY, a support function for activities among humans. HARMONY focuses on only limited human activity, such as collaborative learning for exercises that have a correct answer and answering paths. To support practical human activities, however, we need to update the system to be able to apply it in a wide range of situations. The first step should involve extending it to cope with various types of exercises.

In HARMONY, two mechanisms are introduced for environment-sharing and behavior-sharing. These mechanisms are actually implemented as different systems. Thus, to evaluate the effectiveness of HARMONY, these mechanisms should be integrated and evaluated as one.

When many mechanisms are integrated into one system, students need to use multiple windows containing learning contents during learning. In such situations, students may focus on either a student or a particular window at any given moment. However, in the current form of HARMONY, only environment-sharing among students is focused. Therefore, to realize true environment-sharing, students' intentions toward windows also need to be grasped. Future work will involve developing an interface that reflects students' intentions with respect to all objects in a student's private learning space, such as other students and windows.

REFERENCES

[1] Dillenbourg, P. (eds.): "Collaborative Learning – Cognitive and Computational Approaches," Elsevier Science Ltd. (1999).

[2] Koschmann, T. (eds.): "CSCL: Theory and Practice of an Emerging Paradigm," Lawrence Erlbaum & Associates Publishers (1996).

[3] Watanabe, T.: "Learning Collaboration in a Round Table," *(to be published in HCI 2006)*.

[4] Ito, T., Ohnishi, N., and Sugie, N.: "Problem-Solving SCRIPT and Clarification of Drawings for Explaining Drawing Process," Trans. on IEICE, D-II, Vol. J77-D-II, No. 4 (1994) 811-822 (in Japanese).

[5] Murase, Y., Kojiri, T., and Watanabe, T.: "Dynamic Generation of Diagrams for Supporting Solving Processes of Mathematical Exercises," Proc. of KES 2005, Vol. 3 (2005) 673-680.

[6] Kojiri, T., Murase, Y., and Watanabe, T.: "Group Collaboration Support in Learning Mathematics," Proc. of KES 2006, Part II, LNAI 4252, (2006) 1053-1061.

[7] Ito, Y., Kojiri, T., Watanabe, T.: "Face-to-face Interface for Collaborative Learning Environment," Technical Report of IEICE, ET2002-12, (2002), 7-12, (in Japanese).