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Title: **Supporting Awareness in a CSCL Environment**

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Keywords: CSCL (Computer Supported Collaborative Learning), Awareness, Web-based Education and Teaching, and Information Visualization.

Supporting Awareness in a CSCL Environment

Abstract:

This paper describes Knowledge Awareness (KA), a new concept for inducing collaboration in an open ended and collaborative learning environment. To enhance collaboration opportunities in this situation, KA provides information about the activities of the learners within the shared knowledge space. For instance, the messages are “someone is looking at the same knowledge that you are looking at,” “someone discussed the knowledge which you have inputted.” The spontaneous collaboration that is created by the messages facilitates the refinement and evolution of the learners’ knowledge. This paper also describes *knowledge awareness map* and its design, implementation and evaluation. The map visualizes the relationship between the shared knowledge and the current and past interactions of learners. The map plays a very important role of finding peer helpers, and inducing collaboration. In this map, a mediator agent recommends suitable collaborators who can help the problem solving. SHARLOK II (sharing, linking and looking-for knowledge) has been developed on the web as a testbed of KA map, which has a knowledge building and collaborative learning environment connected via Internet. We have tested and verified the effectiveness of SHARLOK II and KA map through their use.

Keywords: CSCL (Computer Supported Collaborative Learning), Awareness, Web-based Education and Teaching, and Information Visualization.

1. INTRODUCTION

Recently, researchers in the educational systems area attempt to provide technological support for cooperative and collaborative learning advocated by educational theories (O’Malley, 1994; Koshmann, 1996). For example, Lave and Wenger (1991) developed a perspective of situated learning that viewed learning as an ongoing participation in communities of practice. We focus on an open ended and collaborative learning environment by integrating a knowledge-building tool and a collaborative interface tool.

In particular, when learners acquire knowledge in the context of open-ended activities, they are more likely to use that knowledge later. Similarly, in collaborative learning, distributed expertise and multiple perspectives enable learners to accomplish tasks and develop understanding beyond that which any could achieve alone. Therefore, it is very important for learners to collaborate with each other frequently.

For this situation, CoVis (Edelson, Pea and Gomez, 1996), KIE (Linn, 1996), CSILE (Scardamalia and Bereiter, 1996), WebCamile (Guzdial, Hmelo, Hübscher, Nagel, Newstetter, Puntembakar, Shabo, Turnst, & Kolodner, 1997) and Belvedere (Suthers and Jones, 1997) have proposed efficient collaborative learning. CoVis emphasizes making a collaboration process visible. KIE helps students link, connect, distinguish, compare, and analyze their repertoire of ideas. Moreover, CSILE and WebCamile support knowledge building for the creation of knowledge. Belvedere, which is a networked software system, was implemented to provide

learners with shared workspaces for co-ordinating and recording their collaboration in scientific inquiry. In such environments, the learner actively provides his/her own knowledge to the system. However, these systems have given little attention to the technical support for inducing collaboration.

In Computer Supported Cooperative Work (CSCW), *awareness* is one of the most interesting topics, which can increase communication opportunities in a distributed workspace. Dourish and Bellotti (1992) defined *awareness* as "*understanding of the activities of others, which provides a context for your own activity.*" In CSCL (Computer Supported Collaborative Learning), *Knowledge Awareness (KA)* have been proposed to bridge learners who are interested in the same knowledge and to create effective collaboration in a distance learning environment (Ogata, Matsuura and Yano, 1996a; Ogata and Yano, 1997). KA gives learner information about other learners' activities in a shared knowledge space. Its messages are, for instance, "someone is looking at the same knowledge that you are looking at," "someone changed the knowledge which you have inputted." These messages of KA encourage collaboration by exciting learner's curiosity and by active learning.

SHARLOK (*Sharing, Linking and Looking-for Knowledge*) has been developed as a testbed of the KA (Ogata and Yano, 1996b). SHARLOK is an open-ended and collaborative learning environment, and it integrates a knowledge-building tool with a collaborative interface tool. SHARLOK allows learners: (1) to share their respective knowledge in its shared knowledge space, and to explore this knowledge space freely, (2) to make hypertext links between relevant knowledge, and (3) to collaborate about shared knowledge in an ad hoc group at real time. Evaluation of SHARLOK showed that KA encouraged collaboration by exciting learner's curiosity and that KA effectively induced collaboration (Ogata and Yano, 1998). However, the problem arises that it is very difficult for learner to understand the relationships between other learners and knowledge because KA is provided by text messages.

Recently, a number of educational systems are based on WWW. Generally, educational facilities are provided within these systems and the most notable additional need reflected across all of these systems is for facilities to make the presence and action of other users available across WWW. Many systems are tackling this core problem in a number of different ways, e.g., WebVis (Pitkow and Bharat, 1994), WAVE (Kent and Neuss, 1994), CGV (Girardin, 1995) and Footorints (Alan and Maes, 1997). Moreover, Palfreyman and Rodden (1996) developed an open awareness protocol for WWW.

This paper proposes *Knowledge Awareness Map (KA map)* that visualizes KA information on WWW. The map helps learner to mediate and recognize collaborators in the shared knowledge space. On this map, Mediator Agent (MA) identifies learning-companions who can help solving a problem. The characteristics of the map are:

- (1) Visualization of the hyperlinks and categorization of pages on the Web as educational materials,
- (2) Visualization of the relationships between pages and learners to induce collaboration,
- (3) Recommendations of appropriate collaborators on KA map to help find suitable

partners.

We are developing an open-ended collaborative learning support system, which is called *SHARLOK II*. SHARLOK II is a prototype for KA map, and facilities to share individual knowledge and to learn through collaboration on WWW pages. In this paper, first, the outline of SHARLOK II is described.

2. CSCL & AWARENESS

2.1 CSCL

Collaborative learning deals with instructional methods that seek to promote learning through collaborative efforts among students working on a given learning task. Computer Supported Collaborative Learning (CSCL) enhances learning in a dynamic fashion, where the system that delivers the collaborative environment takes an active part in analyzing and controlling collaboration. On the other hand, CSCW deals with collaboration in a passive fashion, where the system that delivers the collaborative environment does not attempt to exercise active control of the collaborative interactions.

Depending on the type of collaborative tasks to perform, CSCL could be employed to address concept-learning, problem solving, and designing. Concept learning deals with a goal as a single entity while the other two deal with a goal in terms of sub-goals. Further, designing is distinguished from problem solving in the sense that the number of solutions in problem solving is finite and computationally easier to represent. Another major factor that regulates collaboration is the theory of learning, based on which collaborative interactions could be categorized into socio-cognitive, socio-cultural, and situated cognition (Dillenbourg and Self, 1994).

A collaborative learning system concentrates on refining and integrating the learning process and the subject knowledge of the students with the help of the partners. The promise of collaborative learning is to allow students to learn in relatively realistic, cognitively motivating and socially enriched learning contexts, compared to other tutoring paradigms like Socratic learning, discovery learning, integrated learning, etc. For instance, the student might discuss the strategies to solve a given problem in a problem-solving domain like trigonometry or practice the colloquial usage of a foreign language in a computer-aided language learning system. With CSCL, the student can discuss these strategies with a group of fellow students who advise, motivate, criticize, compete, and direct the student towards better understanding of the subject matter.

CSCL accommodates active collaboration while CSCW is rather passive. CSCL could be considered as a superset of CSCW since it not only provides the delivery vehicle for collaborative interactions that is provided by CSCW, but also provides the additional controls required to guide collaborative learning in an active fashion, based on the requirements of the peers involved in learning. CSCW simply provides the means for collaboration and it is left to the collaborators to make use of the means in the most effective way possible, while CSCL not only provides the means for collaboration but can also analyze and direct the collaborative interactions based on the content of collaborative

interactions.

2.2 Awareness

In CSCW (Computer Supported Cooperative Work), a collaboration process is lead from four processes (Malone, Lai and Fry, 1994): co-presence, awareness, communication, and collaboration. Co-presence gives the feeling that the user is in a shared workspace with someone at the same time. Awareness is a process where users recognize each other's activities on the premise of co-presence, for example, "what are they doing?", "where are they working?" In the next process, the user collaborates on the specific task with other users and accomplishes the task and common goals. Awareness, in particular, is one of the most interesting topics (Matsushita and Okada, 1995) to achieve cooperation and collaboration and to increase communication opportunities.

Researchers in CSCW have already proposed the following awareness:

- (1) Giving information on the surroundings of the target user, for example, Portholes (Dourish and Bly, 1992);
- (2) Providing common or public space where users can gather and meet, for example, Video Window (Fish, Kraut and Chalfonte, 1990); and
- (3) Simulating informal communicative opportunities in real world using computers, for example, VENUS (Matsuura, Hidaka, Okada and Matsushita, 1995).

The above awareness support systems are implemented using multi-media technologies to bond physically distributed environments.

In CSCL (Computer Supported Collaborative Learning), awareness is also very important for effective collaborative learning and it plays a part in how the learning environment creates collaboration opportunities naturally and efficiently. Goldman (1992) identified three types of student awareness: social, task, and conceptual. Gutwin, Stark and Greenberg (1995) also proposed workspace awareness. Table 1 summarizes the kinds of awareness in a CSCL environment. Social awareness provides information on social relationships within the group to carry out the task, for example, the role in the group. Task awareness shows how the learners accomplish the task. Concept awareness is the awareness of how a particular activity or knowledge fits into the learner's existing knowledge or completes the task. Workspace awareness is the up-to-the-minute knowledge about other learners' interactions within shared workspace. Gutwin et al. implemented this awareness using GroupKit (Roseman and Greenberg, 1992). However, these concepts have not yet included awareness for inducing collaboration in a shared knowledge space.

Table 1: Types of awareness.

| Awareness | Examples |
|-----------|--|
| Social | What should I expect from other members of this group? What role will I take in this group? What roles will the other members of the group assume? |
| Task | What do I know about this topic and the structure of the task? What do others know about this topic and task? How much time is required? How much time is available? |
| Concept | How does this task fit into what I already know about the concept? What else do I need to find out about this topic? Do I need to revise any of my current ideas in light of this new information? |
| Workspace | What are the other members of the group doing to complete the task? What will they do next? What have they already done? |

3. KNOWLEDGE AWARENESS

3.1 What is knowledge awareness?

KA is defined as awareness of the use of knowledge. In a distance-learning environment, it is very difficult for the learner to be aware of the use of other learners' knowledge because the learner cannot understand their actions in the remote site beyond the Internet. KA messages inform a learner about the other learners' real-time or past-time actions that have something to do with knowledge on which a learner was or is presently engaged. These KA messages make the learner aware of someone:

- (1) who has the same problem or knowledge as the learner;
- (2) who has a different view about the problem or knowledge; and
- (3) who has potential to assist solving the problem.

Therefore, these messages, which are independent of the domain, can enhance collaboration opportunities in a shared knowledge space, and make it possible to shift from solitary learning to collaborative learning in a distributed learning space.

3.2 Time and knowledge proximity

As shown in figure 1, we consider two dimensions of messages for KA: time and knowledge separation. KA of type Same Time (ST) informs the learner that other learners are doing something at the same time that the learner is using the system. KA of type Different Time (DT) informs the learner of encounters involving learners' past actions. KA of type Same Knowledge (SK) is a message about other learners' activities towards the same knowledge that the learner is looking at, discussing, or changing. This type is available for learners to find partners who have the same problem or knowledge. KA of type Different Knowledge (DK) enhances a collaboration possibility with another learner (1) who has had something to do with the learner's curiosity; or (2) who has different expertise from the learner's concerns.

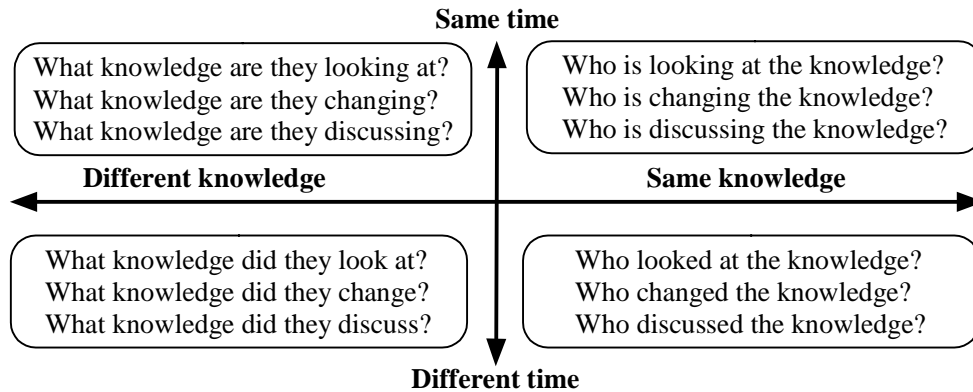


Figure 1: Classification of knowledge awareness.

3.3 Knowledge awareness and curiosity

KA has a close relation with learner's curiosity. Hatano and Inagaki (1973) identified two types of curiosity; Particular Curiosity (PC) and Extensive Curiosity (EC). EC occurs when there is a desire for learning and it makes the learner's stock of knowledge well balanced by widening the learner's interests. PC is generated by the lack of sufficient knowledge, and it is very useful in that the learner can acquire detailed knowledge. KA of type SK excites PC, and KA of type DK satisfies EC. For example, a message of type STDK stirs up the learner's EC by attracting the learner to the particular knowledge when the learner focuses on nothing. Moreover, the message of type STDK about the knowledge leads the learner to collaboration by arousing the learner's PC. In this way, KA induces collaboration by exciting the learner's curiosity.

3.4 Passive and Active Knowledge Awareness

There are two types of KA: passive and active. In the passive KA, the system does not show awareness information until the learner requests it. In contrast, active awareness is autonomously informed to the learner. KA induces spontaneous collaboration between learners using active one. For instance, User-A may start to collaborate with User-B by active KA that informs that User-B has updated the User-A's knowledge. The default of active KA is the same time and same knowledge. However, each learner can modify settings of active KA according to his/her own learning style.

4. KNOWLEDGE AWARENESS MAP

KA map visualizes the strength of the relationships between the shared knowledge and learners. Mediator Agent of each learner acquires and analyzes learner's profile, and it recommends a suitable partner for collaboration in KA map. In our previous research, SHARLOK presented KA information as a text message. From the text message, however, it is very difficult for learner to understand how the other learner is very interested in the knowledge. The other learner may be a vital helper who can assist the learner to understand the knowledge deeply, or may be just looking at the knowledge. Therefore, we propose *Knowledge Awareness Map* that graphically displays KA information. This map provides learner with a clear grasp of some learners around knowledge that is separated from a learner-looking knowledge. With this, the learner can seek for the learner of the discussion

companion interactively. To build KA map, *Mediator Agent* (MA) is proposed, which supports learner to find suitable collaborators concerning the focusing knowledge.

As for the visualization of WWW space, an awareness support system (Palfreyman and Rodden, 1996) was developed in order to displays the links between WWW pages and the users who are accessing the pages into both 2D and 3D representation. This system displays the user who is only referring pages at real-time and the links of the pages. In addition to this, KA map shows the degree of learner's interests and recommends adequate collaborators.

4.1 Mediator Agent

Mediator Agent (MA) bridges a learner who has a question and appropriate companions for creating effective collaboration. The information that MA deals with is shown below:

- (1) Link information: This is link information in the web pages as shared knowledge;
- (2) KA information: This includes the presence and current actions of learners and the degree of the learners' interests; and
- (3) Discussion information: This is about the participants of the discussion.

To provide KA information depends on a learner's action in learning. For providing KA map, learners' actions can be classified into the following:

- (1) Exploration on the web: This action means learner is looking at a web page or looking for a page.
- (2) Requesting for collaboration: Learner is asking for joining discussion.
- (3) Being requested for collaboration: Learner decides whether s/he joins discussion in receiving a request.
- (4) Discussing: Learner is communicating with other learners.
- (5) Idle: This state means learner is doing nothing.

MA manages and provides whether or not learner is using the same knowledge as other learners. Moreover, it watches and stores the current actions of the learner into his/her profile, and MA detects the understanding and interesting degree of the knowledge using learner's profile.

4.2 Learner's profile

MA collects learner's profile with two techniques:

- (1) The action log of learner: e.g., access times to WWW page;
- (2) The explicitly registration by learner.

The actions of learner in an open-ended learning environment can be classified as follows: (A)creating a category, (B)creating knowledge, (C)making link to WWW pages, (D)asking a question, (E)answering the question, (F)modifying knowledge, (G)participate discussion, and (H)looking at knowledge. These eight actions of learner are used as one of learner's profile. However, it is difficult to detect the knowledge and the interest of the learner from learner's actions only. Therefore, it is necessary that the learner register his/her own interests about the knowledge. SHARLOK II realizes the registration of the interests of the learner with *footprints*. Footprint is an explicit flag that shows learner's interest about a shared knowledge.

4.3 Strategy for recommending peer learners

When learner asks a question and seeks for a helper, MA recommends one to three persons. The type of the learner who participates in collaboration is shown below:

- (1) Questioner: This learner has some questions and requires collaboration.
- (2) Answerer: This learner answers the question of the questioner.
- (3) Participant: This learner is interested in the question and wants to join into the collaboration.

MA recommends an answerer who can help problem-solving and some participants to a questioner. MA selects a learner using the following information:

- (1) The login situation of learners:
Because of real-time discussion, MA selects only logged-in users as candidates.
- (2) The footprints of each learner:
Participants are selected from those who put the footprint in the knowledge (page) of the question.
- (3) The profile of each learner:
Although the profile consists of the number of action times to the knowledge, MA has to evaluate totally. If the total of (A)-(D) actions of a learner is larger than that of (E)-(H) actions, then MA considers the learner as an answerer. Otherwise, the learner is a participant. The larger the total of a learner's actions, the more the learner is preferred to join into collaboration.
- (4) The current action of learner:
MA gives a high priority to learners who are doing nothing (idle) in the learning environment. This consideration activates passive learners by stimulating their intellectual curiosity.

This paper proposes the level of interest (LOI) as follows:

$$LOI = \left\{ F + \frac{\text{The number of the learner's actions to the page}}{\text{The max number of other learner's actions to the page}} \right\} \times \frac{1}{2}$$

Variable F shows the footprint that is explicitly given by learner. A footprint is a kind of mark that means learner is interested in knowledge in the web page. The value of F is 1 if learner takes a footprint to the page, otherwise 0. The range of LOI is from 0.00 to 1.00. The more the learner is interested in the page, the larger the LOI is. The first member of the above equation shows learner's interest explicitly. On the other hand, the second member means implicit interest of the learner, which is derived from learner's actions on the page. If a learner takes actions (e.g. visiting, asking a question etc.) to a web page more than the other learners, then the LOI to the page is larger. In this way, the LOI is calculated by taking the average of the both of them.

4.4 Visualization of KA

A link in KA map shows the relationship between web pages and learners. The length (L) of a link means the strength of the relationship and it is calculated by the following equation:

$$L = D(2 - LOI)$$

where, D is a default value of link length.

The range of L is from D to $2D$. If a learner is very interested in a page, the link length (L) of between the page and the learner becomes short and nearing to D .

5 SHARLOK II

SHARLOK II is an open-ended and collaborative learning environment, which consists of a shared knowledge space and a collaborative learning environment.

5.1 An open-ended collaborative learning environment

The characteristic of the open-ended and collaborative learning environment is shown below:

- (1) Learner can participate learning with SHARLOK II at anytime / anywhere.
- (2) The shared knowledge space of learners is extensible.
- (3) Learners collaborate about the shared knowledge, and each learner can access the collaboration results.

In a closed learning environment like a traditional classroom, teacher gives a purpose and a problem of the learning. The learning progresses in the form that the teacher instructs the knowledge to archive the purpose. In an open-ended learning environment, learner carries out his/her tasks while the learner solves some problems in an ad hoc group. In this situation, the learner finds problems in achieving the task and s/he can solve them by collaboration. This paper focuses on WWW as a place where the above environment can be realized. Moreover, WWW has a lot of rich information of and unspecified multitude the learner can be secured by using WWW.

5.2 System configuration

Figure 2 shows the system architecture of SHARLOK II. The system consists of a server and a client. The server includes a WWW server, mediator module, map server and four data.

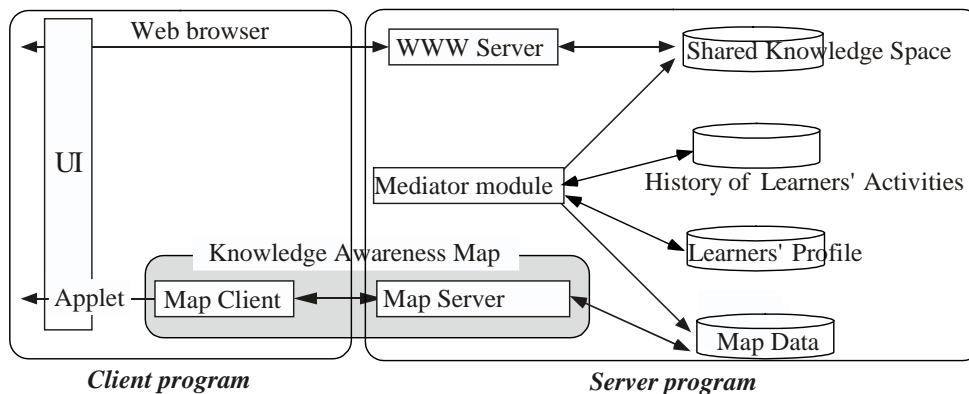


Figure 2: System configuration.

5.3 Collaborative learning environment

SHARLOK II provides the shared knowledge space, where learners provide and share their own knowledge and collaboratively collect and use the knowledge on WWW pages in order to solve problems. When collecting available pages into the shared knowledge space, users have to classify pages into some appropriate categories that teachers have created. These

categories help learner to seek for desired information. SHARLOK II facilitates learners to collaborate about the shared knowledge. Synchronous and asynchronous collaboration can be realized with email, a bulletin board, or a chat tool. Learner is able to solve problems and to acquire new knowledge through collaboration. Moreover, the results are accumulated into the shared knowledge and they are accessible for learners.

Interface of the collaborative learning environment of SHARLOK II is shown in Figure 3. The left side shows an interface to a questioner, and the right side shows an interface to an answerer or a participant. Screen (a) is a main window of SHARLOK II. The learner can access to knowledge (page) in the right frame on window (a). The left frame of the window (a) shows the SHARLOK II functions, e.g., create WWW page, keyword search and so on. Window (b) is displayed in opening a page. The discussion is requested by clicking the "collaboration" button. Then, window (c) is shown, where MA recommends suitable collaborators for the question, and learner can arrange other learners who the learner wants to join into the discussion. The request status is displayed on the right frame of window (a).

Window (d) in figure 3 finally displays the candidates who the learner requests collaboration. Then, a dialogue widow in the screen of another learner appears to have required discussion. The dialogue includes the questioner's names, the page title that has required to the discussion, and a knowledge name, and the title of the question. If the learner accepts a discussion request, then the learner can participate to the discussion with a chat tool. Moreover, the title of discussion appears at the bottom frame in window (a). A learner can join a discussion on the way at anytime by selecting a title of discussions at that frame. The text in the discussion is stored as organizational memory and each learner can see that.

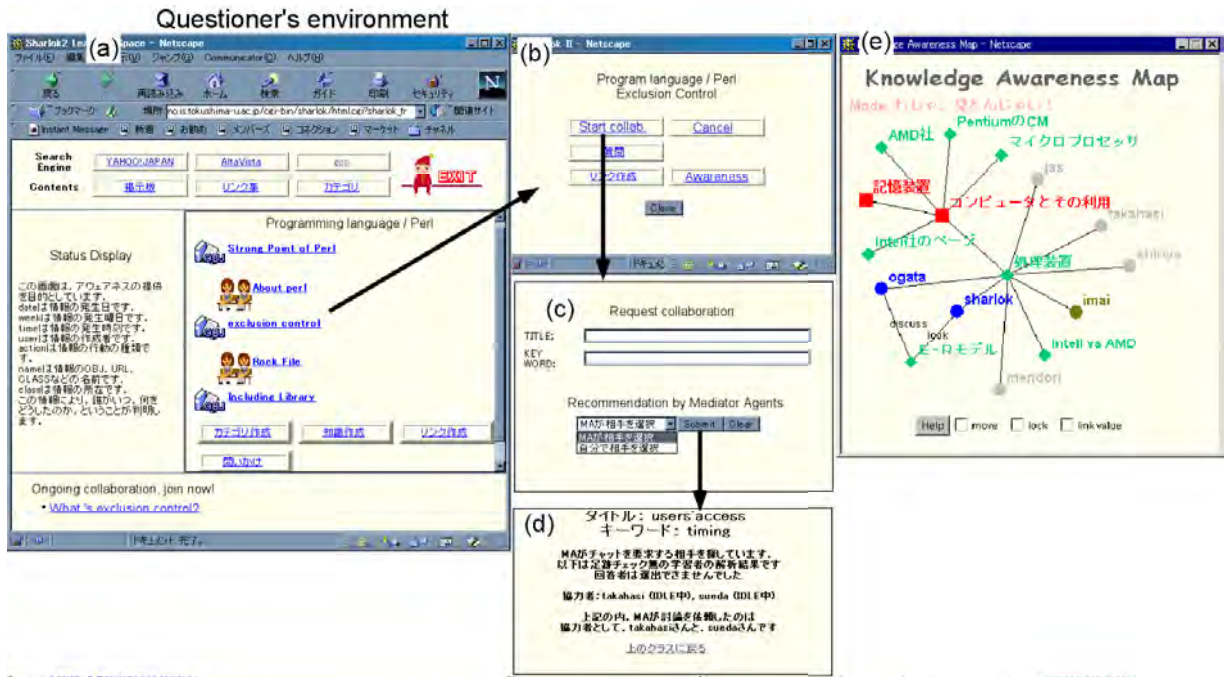


Figure 3. Knowledge awareness map in SHARLOK II.

5.6 KA Map

KA map is shown in window (e) in figure 3. The map is displayed in opening SHARLOK II. When the user “imai” is looking at page (X), window (a) is appeared. The nodes of window (e) consist of categories of web pages, web pages that belong to the same category, and learners. Moreover, MA identifies learners on the map into the user, a questioner, an answerer, a participant and the others when the user starts to request discussion. A close line means the learner is strongly interested in the page. When the user is looking for learning companions about a topic, the user can find peer learners who have strong interests, using this map. When a user poses a question, the user can comprehend who is an appropriate answerer through this graphical map. Moreover, when the user receives the invitation of discussion from another learner, the user can understand the backgrounds of the inviting learner. By clicking a person node, both the personal information of the learner and his/her past actions about peripheral knowledge are displayed.

6. EXPERIMENTAL USE

We have evaluated the effectiveness of KA map by analyzing user's action log.

6.1 Methods

In this experiment, fourteen graduated students used SHARLOK II during three days, one and half an hour respectively. Before the experimentation, we have already explained how to use this system and the users inputted knowledge into WWW page according with their own topics of interest. The users used the following systems of SHARLOK II in each day:

- (1) System-A: Without KA map and Mediator Agent (MA), providing only user names using currently;
- (2) System-B: System-A + passive KA;
- (3) System-C: System-B + KA map.

In the passive KA of System-B, the system does not show awareness information until the learner requests it. In contrast, KA map of System-C autonomously changes its contents and informs KA to the learner.

6.2 Experimental results

They created 22 classes (for example, language learning, databases, and computer science) and 71 pages. If learner had a question about the content of a page in SHARLOK II, the learner found other learners who can help problem solving and started collaborative learning 19 times. The number of participants is from four to six and the participants discussed for 25 minutes. To evaluate KA map, three equations are proposed:

$$\text{Realized Collaboration rate} = \frac{\text{The number of people presenting to collaboration}}{\text{The number of people invited to collaboration}} \times 100$$

$$\text{Utterance rate} = \frac{\text{The number of speakers}}{\text{The number of participants}} \times 100$$

$$\text{Solution rate} = \frac{\text{The number of sessions where the problems were solved}}{\text{The total number of collaboratative sessions}} \times 100$$

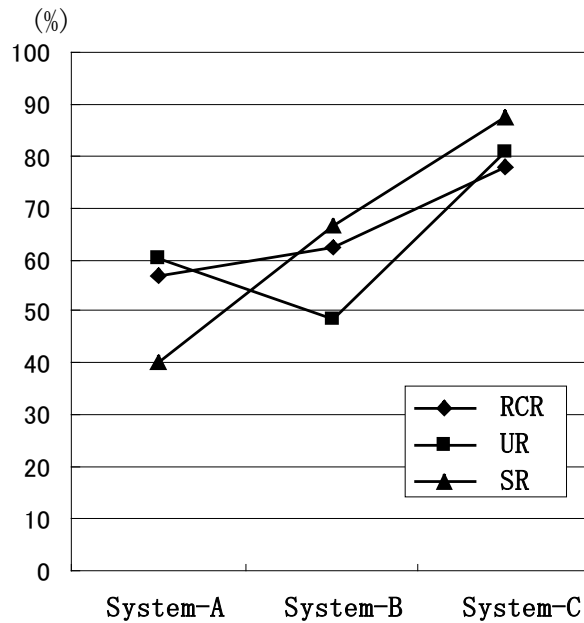


Figure 4. The experimental results.

These rates are high if MA recommended appropriate partners for collaboration. The experimental results are shown in Figure 4. The results of Realized Collaboration Rate (RCR) were, system-A 57.1%, system-B 62.5%, and system-C 77.8%. Utterance Rate (UR) was system-A 60.0%, system-B 48.6%, and system-C 80.6%. Solution Rate (SR) was system-A 40.0%, system-B 55.7%, and system-C 87.5%. The results of system-C were the highest. These results show KA map is excellent at looking for suitable collaborators.

7. CONCLUSIONS

This paper proposed KA map that supports learner to find appropriate companions for his/her problem-solving in an open-ended collaborative learning environment. Moreover, Mediator Agent (MA) was proposed for recommending suitable partners. To evaluate KA map and MA, SHARLOK II was developed on WWW. The result of the evaluation is the following.

- (1) By the agency of MA, it is possible to discuss with the appropriate companion.
- (2) With the agency support, the learner can do lively discussion.
- (3) By the lively discussion, the contents of the discussion can be put to the learner in the impression.
- (4) In order to use KA map helping, it is possible to correspond in case of the analysis failure of MA.

In the future work, the representation and acquisition of learner's profiles and how to use them will be re-considered. Then, SHARLOK II will be used in a classroom at our University, and be evaluated once again for a long term.

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