Knowledge Awareness Map
for Open-ended and Collaborative
Learning on World Wide Web

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This paper proposes an open-ended and collaborative learning environment, called *SharlokII*. In this environment, the learners provide and share individual knowledge and other knowledge on the World Wide Web and discuss about them. This paper 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. SharlokII has been developed and used it experimentally.

Keywords: **Computer Supported Collaborative Learning, Internet and Web Application, Knowledge Awareness, Mediator Agents, Information Visualization.**

1. Introduction

Recently, researchers in the educational systems area are attempting to provide technological support for cooperative and collaborative learning advocated by educational theories[14] [18] [20] . This paper focuses on an *open ended and collaborative learning environment*. For this situation, CoVis[3] , KIE[8] , CSILE[17] , WebCamile[5] and Belvedere[18] have been developed. CoVis focuses on making a collaboration process visible. KIE succeeds by helping students link, connect, distinguish, compare, and analyze their repertoire of ideas. CSILE and WebCamile support knowledge building for the creation of knowledge. Moreover Belvedere that is a networked software system, was implemented to provide learners with shared workspaces for coordinating and recording their collaboration in scientific inquiry. In such environments, distributed expertise and multiple perspectives enable learners to accomplish tasks and develop understandings beyond what any could achieve alone. Therefore, it is very important for learners to collaborate with each other. However, little attention has been given to the technical support for inducing collaboration in distributed leaning spaces connected via Internets.

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[2] defined *awareness as "understanding of the activities of others, which provides a context for your own activity."* This context is used to ensure that individual contributions are relevant to the distributed group's activity as a whole, and to evaluate individual actions with respect to group goals and progress. The information, then, allows groups to manage the process of collaborative working.

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[10] [12] . KA gives each 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 input." 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[11] . 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[13] . However, the problem arises that it is very difficult for a 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. A variety of systems are tackling this core problem in a number of different ways, e.g., WebVis[16] , WAVE[7] , CGV[4] and Footprints[1] . Moreover, Palfreyman and Rodden[15] developed an open awareness protocol for WWW.

This paper proposes *Knowledge Awareness 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 identifies learning-companions who can help solving a problem. We are developing an open-ended collaborative learning support system, which is called *SharlokII*. SharlokII 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 SharlokII is described.

2. SharlokII

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

2.1 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 SharlokII anytime / anyplace.
   (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. On the other hand, 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.

2.2 Shared knowledge space

SharlokII provides the shared knowledge space, where learners provide and share their own knowledge. Also, in SharlokII, they 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.

2.3 Collaborative environment

SharlokII 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.

3. 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.

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 can not understand their actions in the remote site beyond Internet. KA messages informs a learner about the other learners' real-time or past-time actions: look-at, change, and discuss, that have something to do with knowledge on which a learner was or is presently engaged. For example, KA messages are "someone is changing the same knowledge that you are looking at", "someone discussed the knowledge which you have input." These 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 that 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.

KA messages are classified into two dimensions: 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. By using learners' past actions, KA of type different time (DT) provides the encounters beyond time. KA of type same knowledge (SK) is a message about other learners' activities to 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 collaboration possibility with another learner (1) who has had something to do with the learner's interests; or (2) who has different expertise from the learner's interests.

For example, the message of type STSK, "Who is looking at the knowledge?" shows the existence of learners who are looking at the knowledge that the user is looking at. By this message, the user may start to discuss on the knowledge. Likewise, the message of type DTSK "Who changed the knowledge since I have last looked at?" facilitates to start discussion on the changing of the knowledge. Moreover, the message of type STDK "What

knowledge are they discussing?" is useful to join into the discussion which interests the learner.

3.2 Knowledge Awareness map

In our previous research, Sharlok presented KA information as a text message. From the text message, however, it is very difficult for a 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[15] 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 to pages in 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.

3.3 Mediator Agent

Mediator Agent bridges a learner who asks a question and appropriate companions for creating effective collaboration. The information that MA deals with is shown below:
  (1) The existence of learners;
  (2) The current action of learners;
  (3) The degrees of the learners' interest; and
  (4) The progress of discussion.

MA manages and provides whether the learner is using the same knowledge as another learner, or not. 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.

3.4 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 a 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 in discussion, and (H)looking at knowledge. These eight actions of learner are used as one of learner's profile. However, it is difficult to judge the knowledge and the interest of the learner from learner's actions only. Therefore, it is necessary that learner registers his/her own interests on the knowledge. SharlokII realizes the registration of the interests of the learner with *footprints'*. Footprint is an explicit flag that shows learner's interest in a shared knowledge.

3.5 Strategy for recommending peer learners

When learner asks a question and seeking 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 loged-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.

4. Implementation of Knowledge Awareness Map

SharlokII is a client-server system that is developed with Java1.1 and Perl5.0 program languages. Learner accesses SharlokII through WWW Browser.
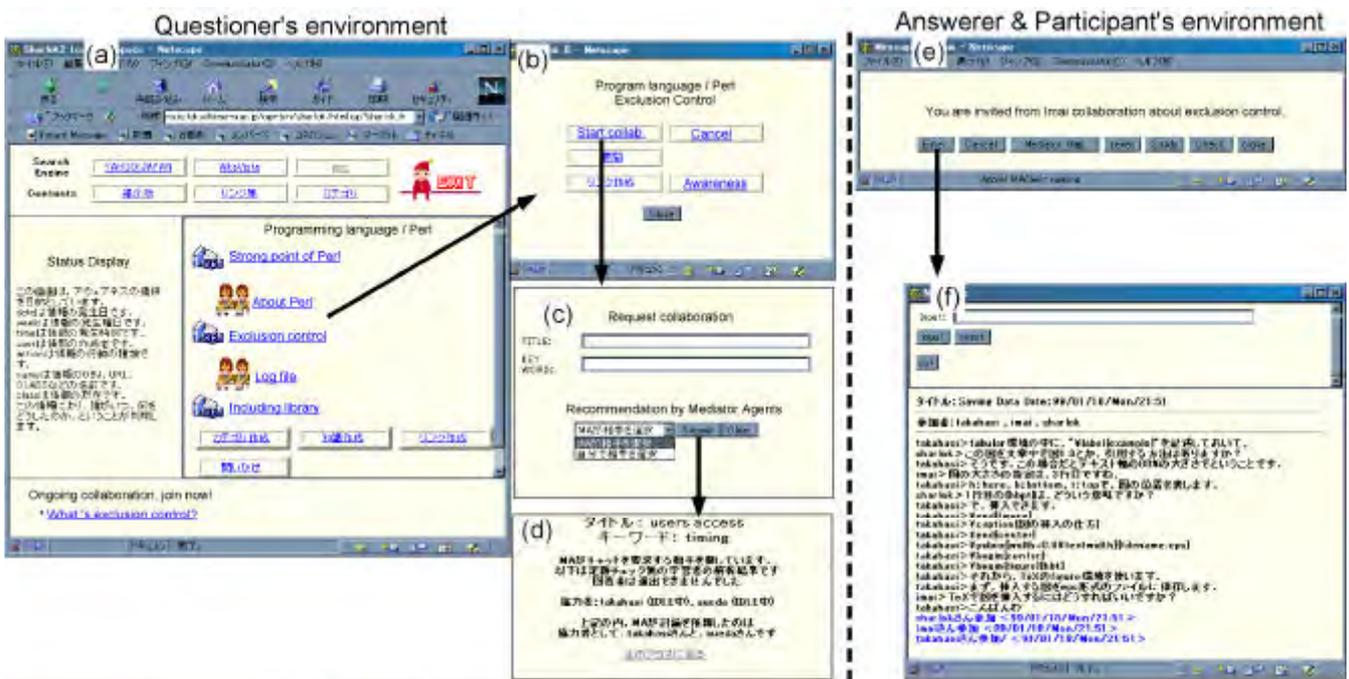

Figure 3.   Knowledge awareness map.

4.1 Collaborative learning environment

Interface of the collaboration learning environment of SharlokII is shown in Figure 2. The left side shows an interface of a questioner, and the right side shows an interface of an answerer or a participant. Screen (a) is a main window of SharlokII. The learner can access

to knowledge (page) in the right frame on window (a). The left frame of the window (a) shows the SharlokII 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 leaner can also arrange other learners who the learner wants to join into the discussion. The request status is displayed on the right frame of window (a).
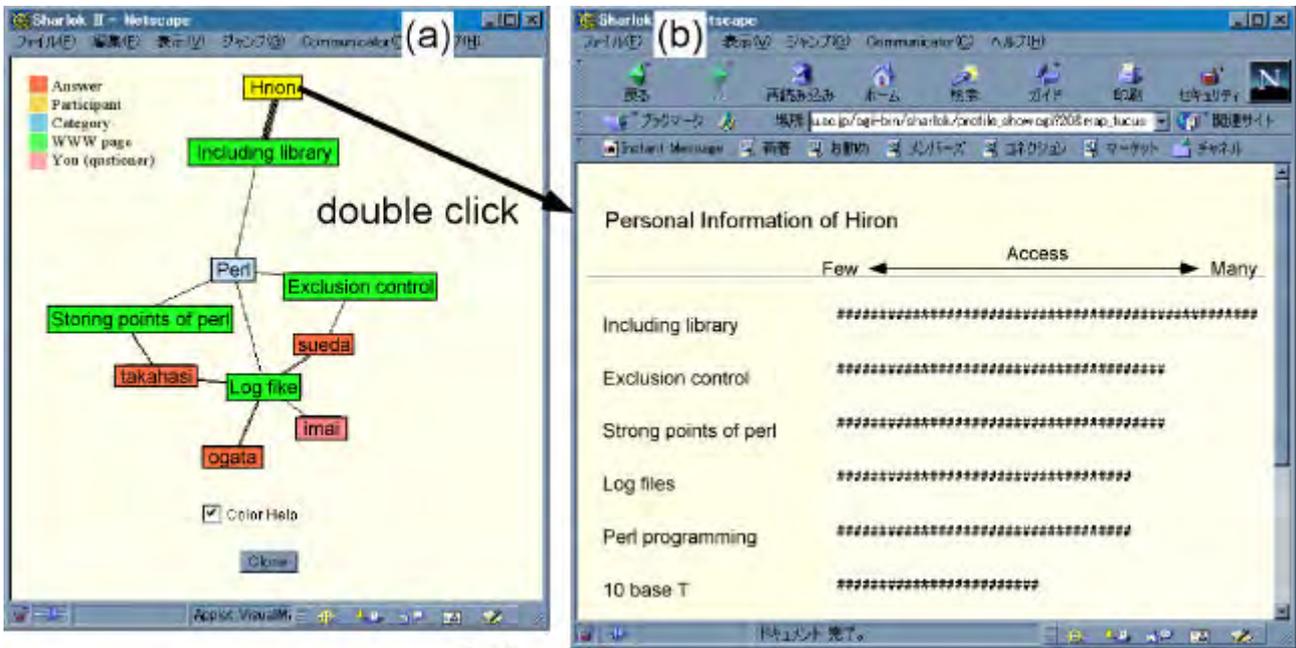

Figure 3. Knowledge awareness map.

Window (d) in figure 2 finally displays the candidates who the learner requests collaboration. Window (e), (f) are the screen of another learner to have required discussion. Window (e) displays an invitation message from the questioner. The message includes the questioner's names, the page title that has required to the discussion, and a knowledge name, and the title of the question. With the "OK" button on window (e), the learner accepts a discussion request, and then the learner can participate in the discussion. In window (f) the learner can start collaboration. If the requested learner rejects the invitation, the questioner can know that in status window (a).

4.2 KA Map

KA map is shown in window (a) of figure 3. The map is displayed in opening SharlokII. Nods of window (a) consist of a category, a WWW page that belongs to the same category, and learner. Moreover, MA identifies learners on the map into the user, a questioner, an answerer, a participant and the others. A thick line means the learner is strongly interested in the knowledge. When the user looks for learning companions about a topic, the user can finds peer learners who has strong interests, using this map. When the user requests 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, window (b) shows both the personal information of the learner and his/her past actions about peripheral knowledge that the leaner is focusing on. On the other hand, if the user selects a page node in window (a), then the corresponding page is displayed in window(a) of figure 2.

5. Experimental Results

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

5.1 Methods

In this experiment, fourteen graduated students used SharlokII during four days, four hours respectively. On the first day, we explained how to use this system and the users inputted knowledge into WWW page according with their own topics of interest. From the second day, the users used the following systems of SharlokII in each day:
 (1) System A: Without KA map and Mediator Agent, providing only user names using Currently;
 (2) System B: System A + KA map;
 (3) System C: System B + mediator agent.

5.2 Experimental results

They created 33 classes (for example, language learning, databases, and computer science) and 126 pages. If leaner had a question about the content of a page in SharlokII, the learner found other learners who can help problem solving and started collaborative learning 68 times. To evaluate KA map, two equations were proposed:

$$Realized\ Collaboration\ rate = \frac{The\ number\ of\ people\ asenting\ to\ collaboation}{The\ number\ of\ people\ invited\ to\ collaboation} \times 100$$

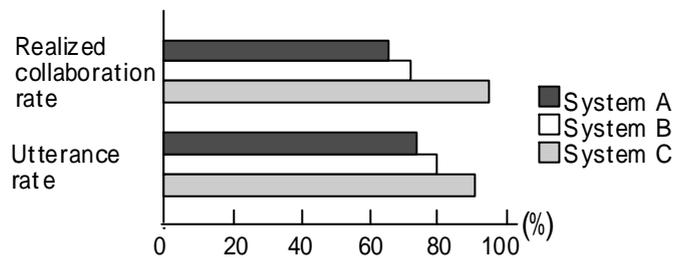$$Utterance\ rate = \frac{The\ number\ of\ speakers}{The\ number\ of\ participants} \times 100$$

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 are, system A 62.5%, system B 68.4%, and system C 88.9%. The rate of system C is the highest of the others. This result shows KA map and MA is very effective to looking for suitable collaborators. Next, the results of utterance rate are, system A 74.3%, system B 80.0%, system C 87.8%. These results also show KA map is quite excellent.

6. 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 was proposed for recommend suitable partners. To evaluate KA map and MA, SharlokII was developed on WWW. The result of the evaluation is as 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 to do lively discussion.

(3) By the lively discussion, the contents of the discussion can be put to the learner in the impression.

(4) In to use KA map helping, it is possible to correspond in case of the analysis failure of MA.

In the future, it considers the composition of learner profile and a way of making more, it improves the analysis precision of MA and it evaluates once again.

Acknowledgement

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