Knowledge Awareness: Bridging Learners in a Collaborative Learning Environment

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ABSTRACT

This paper describes ***knowledge awareness*** (KA), a new concept for inducing collaboration in an open ended and collaborative learning environment. ***Sharlok*** (sharing, linking and looking-for knowledge) is also proposed as a testbed of KA, which has a knowledge building and collaborative learning environment connected via Internet. 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 which is created by the messages, facilitates the refinement and evolution of the learners' knowledge. We have tested and verified the effectiveness of Sharlok and KA through their use.

INTRODUCTION

Open ended CAI (Computer Assisted Instruction) systems have been proposed to support the learner making his/her knowledge stable by acquiring knowledge from the learner (Yamamoto et al., 1989; Yano et al., 1992). Their extensive knowledge bases have also facilitated to enhance learning and to keep learners motivated. We will attempt to extend open ended CAI to a multi-learners environment.

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 such 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 & Gomez, 1996), KIE (Linn, 1996), and CSILE (Scardamalia & Bereiter, 1996) 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 supports knowledge building for the creation of knowledge. However, these systems have given little attention to the technical support for inducing collaboration.

We propose ***knowledge awareness*** (KA) in ***Sharlok*** (sharing, linking and looking-for knowledge), in which the learning environment integrates a knowledge building tool with a synchronous collaborative interface tool. Sharlok allows learners: (1) to store their respective knowledge in its shared knowledge space, to explore it freely, (2) to make hypertextual links between relevant knowledge, and (3) to collaborate with the knowledge in an ad hoc learning group.

To bridge learners who are interested in the same knowledge and create effective collaboration in Sharlok, KA gives the learner the information about other learners' activities in 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." We believe that these messages can lead the learner to collaborate with others.

AWARENESS

Awareness in CSCW

In CSCW (computer supported cooperative work), a collaboration process is lead from four processes (Malone, et al. 1994); co-presence, awareness, communication, and collaboration. Co-presence gives the feeling that the user is in a shared work space 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 & Okada, 1995) to achieve cooperation and collaboration and to increase communication opportunities.

Researchers in CSCW have already proposed the following awareness:

(1) to give information on the surroundings of the target user, for example, Portholes (Dourish & Bly, 1992);

(2) to provide common or public space where users can gather and meet, for example, Video Window (Fish, Kraut & Chalfonte, 1990); and

(3) to simulate informal communicative opportunities in real world using computers, for example, VENUS (Matsuura, Hidaka, Okada & Matsushita, 1995).

These awareness are implemented using multi-media technologies to bond physically distributed environments.

Yamagami & Seki (1993) have proposed KA that gives background to the cooperative activities with increased emphasis on sharing know-how of an organization. They have developed an asynchronous information sharing system called FISH (Flexible Information Sharing System), and pointed out the importance of KA as a shared feeling of mutual willingness to share information. However, the aim of this KA is not to induce collaboration in CSCL environments.

Awareness in CSCL

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 et al. (1995) also proposed workspace awareness.

Table 1 summarizes those awareness. 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 & Greenberg, 1992). However, these concepts have not yet included awareness for inducing collaboration in a shared knowledge space.

Insert Table 1 here.

KNOWLEDGE AWARENESS

What is Knowledge Awareness ?

We assume that KA is the information about other learners' activities used to enhance collaboration opportunities in a shared knowledge space. To support shifting from a personal learning environment to a collaborative one, KA informs their real-time or past-time actions that have something to do with the knowledge on which the learner is working or had already completed. KA makes a learner aware of the knowledge of someone: (1) who has the same knowledge as the learner, (2) who has a different view about the learner's knowledge, and (3) who has a relationship to the learner's knowledge. This information does not force the learner to establish any collaboration, based on a learner-centered and open-ended design.

KA is very useful for creating new collaboration during individual learning. Though the four awareness (social, task, concept, workspace) are needed after deciding to start the collaboration, KA is required before the beginning of the collaboration. The characteristics of KA are (1) collaboration starts based on the motivation of learners; (2) participants of it are ad hoc; and (3) its tasks are unscheduled.

Monitoring and Informing Learner's Actions

Learners' activities in the shared knowledge space are divided into *looking at*, *changing* and *discussing* knowledge. *Changing* includes creating, updating and deleting knowledge in the shared knowledge space. The information about these actions helps a learner become conscious of other learner's knowledge. For instance, the *changing* information that someone has updated the knowledge which he/she has offered, supports him/her to be aware of someone who has a different aspect from him/her. Therefore, it is necessary to monitor and save these three activities for proving KA.

Time and Knowledge Proximity

We consider two dimensions of messages for KA: time and knowledge separation (see Table 1). 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 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 the knowledge. Likewise, the message of type DTSK "Who changed the knowledge since I have last looked at?" facilitates discussion on the changing of the knowledge. Moreover, the message of type STDK "What knowledge are they discussing?" is useful to enter the discussion which interests the learner.

Insert Table 2 here.

Knowledge Awareness and Curiosity

KA has a close relation with learner's curiosity. Hatano & Inagaki (1973) divide curiosity into two types; particular curiosity (PC) and extensive curiosity (EC). EC occurs through the desire of learning and it makes learner's stock of knowledge well-balanced by widening learner's interests. On the other hand, PC is generated for the lack of sufficient knowledge, and it is very useful to enable the leaner to acquire detailed knowledge. KA of type SK excites PC, and KA of type DK satisfies EC. For example, the 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 learner's curiosity.

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. Sharlok induces spontaneous collaboration between learners using active awareness. For instance, User A may start to collaborate with User B by active KA which informs that User B has updated the User A's knowledge. The default of active KA is the same time and same knowledge. But each learner can modify settings of active KA according to his/her own learning style.

How to Provide Active Knowledge Awareness

Since learners simultaneously use some knowledge in shared knowledge space, many messages of active KA are provided at the same time. Such massage are often an overload for learners. Therefore, the system determines whether or not the messages of KA disturb learning, and it has to provide only the appropriate message.

When a learner engages in learning (e.g., discussion), the messages of active KA may disturb him/her. We identify the way to provide KA: direct and indirect (see Table 3). If a learner is looking at or changing knowledge and another learner focuses on the same knowledge, KA-Agent directly shows the learner KA of type SK by using a dialogue. If the learner concentrates on learning and another learner approaches the other knowledge, KA-Agent had better not display KA of type DK directly to bother the learning. Likewise, KA should indirectly be provided when the learner engages in discussion. The learner can see KA after finishing the discussion if he/he wants. Otherwise the learner does nothing (i.e., idle), KA-Agent informs him/her KA directly to recognize which knowledge other learners are interested in.

Insert Table 3 here.(Strategy for providing KA according to learner's action.)

SHARLOK

Open Ended and Collaborative Learning Environment

The main features of the learning environment in Sharlok are the following:

(1) The shared knowledge base of Sharlok is extendible to acquire knowledge from learners. Since Sharlok allows learners to share their respective knowledge, they can cover the lack of their mutual knowledge.

(2) The users of Sharlok are not limited if they can use Internet. Every user can explore in shared knowledge space according to their interests.

(3) Learners can link between relevant knowledge as a hypertextual link. By using this shared hypertextual knowledge space, they can learn covering the multi-domain.

(4) By creating or joining collaboration about the knowledge during its use, learners can confirm or correct the knowledge. The participants of collaboration are ad hoc and several collaboration are concurrently opened. The process of collaboration is recorded and it can be accessed by every learner.

Framework

Figure 1 shows the framework of an open ended and collaborative learning environment in Sharlok. This framework includes personal learning environment, awareness, and collaborative learning environment. A learner stores his/her important and useful knowledge into a shared knowledge space like his/her memo or notebook. The shared knowledge space allows learners to look up and link knowledge according to their own interests and viewpoints. In this way, learners can supplement their lack of knowledge. In such processes, they can correct or refine the shared knowledge by discussion. Awareness module bridges shared knowledge space and collaboration, and it increases collaborative opportunities. By this awareness, collaboration is created and refined more frequently. It also builds on learners' knowledge as well as shared knowledge. In this way, awareness offers mediation between shared knowledge space and discussion. Based on this process, Sharlok uses ***Holmes*** (hypertext and semi-object oriented learners' memory system) as a shared knowledge space, knowledge awareness enhances collaborative chances. The collaboration is supported by GroupKit.

Insert Figure 1 here.(Framework of an open ended collaborative learning environment.)

Personal Learning Environment

Holmes is a personal learning environment of Sharlok. Holmes has the following functions:

(1) the definition of a class;

(2) the creation of an instance object of a class;

(3) browsing search for objects;

(4) the authoring of links between heterogeneous objects; (5) the navigation of objects.

Holmes handles shared knowledge using *TRIAS* (Yamamoto et al., 1989) which allows users to add, delete or change attributes or values at any time during its use. TRIAS represents data with triplets of small grain size elements as (object, attribute, value). It automatically links triplets which have the same element.

The start-up window of Sharlok is Figure 2 (a). The class hierarchy in Sharlok is shown in *ObjectTree* of Figure 2 (b). The window enables learners to create and define a new class. Learners can create objects and input their knowledge to an object window (see Figure 2 (c)). An object has a pair of an attribute and a value, a text data and a sketch data. The question button in the window is a trigger to start collaboration. Sharlok displays learners' respective message window to create the collaboration, for example Figure 2 (e). If the learner pushes the "Yes" button in the window, the learner becomes a participant of the collaboration.

Insert Figure 2 here. (Screen of a personal learning environment in Sharlok.)

Collaborative Learning Environment

Figure 3 shows an example object for collaboration in Sharlok. Its participants are *tsutsumi*, and *shao*. This object includes a text chat tool, and a group drawing tool. In the text tool, the participants can write their respective idea(s). Moreover, the drawing tool shows their mouse pointers and allows them to draw figures at the same time. Holmes stores the processes of the collaboration and makes them retrievable for all the learners.

Insert Figure 3 here. (Screen of a collaborative learning environment in Sharlok.)

IMPLEMENTATION OF KNOWLEDGE AWARENESS

Sharlok consists of several clients and a server connected via Internet, and it is implemented in Tcl 7.4jp and Tk 4.0jp on Sun Unix Workstations. As of this writing, various versions of this system have been used intermittently by more than seven people in our laboratory over a period of one year. Over 40 copies of the software have distributed to other researchers and developers for demonstration purposes.

Architecture

Based on the architecture in Figure 4, we developed KA. The server has a shared database and a history database of learners' actions. A client consists of a student monitoring, passive KA, active KA and user interface modules. Sharlok monitors the learners' activities in the shared knowledge space and stores them into the history database. There are two kinds of KA's message(s) in Sharlok: passive and active. Passive KA is displayed when the learner requests the learners' history. In contrast, an active KA is generated by periodically executing rules which are triggers for the display of messages. The active KA module is continuously watching the history database like agents.

Insert Figure 4 here.(Architecture of knowledge awareness.)

Recording Learner's Actions

Learners' history is represented by "Who", "When", "What", and "How" attributes of triplets (see below). "Who" is a learner's name that is doing or did actions; "What" is the object; "When" is the time and date of the action; and "How" is the learner's action. These histories are recorded after operating Sharlok's interface. For example, "changing" action is stored by pushing the save button.

Passive Knowledge Awareness

Learners can obtain the KA through the two pull-down menus in Figure 5 (a) and (b). The DK type KA is given by (a), and the SK type KA is (b). When a learner requests KA by selecting the menu, Sharlok tells him/her the information by querying the history database, as shown in Figure 5 (c). This window shows the object names, the beginning time of the respective conferences, and its participants. The learner can start or join the collaboration by selecting the collaboration button. In this case, Sharlok displays the result of "What knowledge did they look at?".

Customization of Active KA

Learners would like to see only the important parts of the KA information instead of all of it. Therefore, the system allows them to customize the activation of KA from the view of knowledge (object) and actions in order to provide only the learner-required information.

(1) *Knowledge (Object)*: Sharlok provides two ways for setting interesting objects. One is based on a class-instance of an object-oriented database and the other uses hypertext links.

(1-A) *Class based customization*: In Figure 2 (b), a learner can select target classes for active KA. If someone approaches the instance of either the target classes or their respective subclasses, then the learner will be aware of another learner's action.

(1-B) *Instance based customization*: A learner sets interesting objects by leaving his/her own footprints (see Figure 2 (c)). If someone uses these objects, then Sharlok automatically informs it.

(1-C) *Link based customization*: Some objects connected by hypertextual links have something to do with each other. For example, Sharlok actively informs KA about some knowledge that is separated at less than 2 units of distance from the one which the leaner is looking at.

(2) *Learner's action*: In addition to the knowledge customization, a learner can select other

learners' actions which are informed by active KA. For example, the system will inform all the "looking-at", "changing" or "discussing" actions.

Active Knowledge Awareness

According to the customization of active KA, Sharlok autonomously displays KA in the message window (see Figure 5 (d)). The learner can start or join the discussion by selecting the "Yes" button. By this message, a learner will be able to collaborate about "problem on triangles" with "ogata". In this way, it is possible for KA to connect each learner.

Insert Figure 5 here. (Screen of knowledge Awareness.)

Knowledge Awareness Map

"Knowledge Awareness Map" window graphically displays recorded history in view knowledge and time. This map provides learners with a clear grasp of some history about knowledge that is separated from a learner-looking knowledge. Figure 6 shows this map for the example of a physics object shown in Figure 2. The shadow area of the map denotes the range of a learner's preference of active KA. Sharlok automatically informs learners actions about knowledge linked directly from the learner-looking knowledge, taken from one hour ago to the present time.

According to the distance of links and time, buttons are placed into the map. The button labels denote the number of the recorded histories related with knowledge at that point of time. For example, at the point of time 4, there are 5 histories. Using the button, "Knowledge Awareness List" window displays the histories in detail. The shown items are who, when, how, and object. The "Show Knowledge" button displays the selected object, and the "Collaboration" button opens a collaboration with a selected learner.

Insert Figure 6 here. (Screen of knowledge awareness map.)

EXPERIMENTAL RESULTS

We tested and verified the effectiveness of KA and Sharlok.

Methods

To evaluate the effectiveness of Active KA, we integrated a group of nine master course students who had been using Sharlok for a period of seven days, during at least two hours every day. First, the members inputted data according with their own topics of interest. They created 65 classes (for example, Japanese Kanji, math., and computer science) and 1,335 objects. After that, we divided the group in three sub-groups; group A was not provided KA, group B was allowed to use passive KA, and group C was provided both passive and active KA. Then the respective members began to explore the shared database and to discuss without teacher's instruction.

Results

Questionnaire

We evaluated the learning environment of Sharlok with a questionnaire. Learners had to answer giving a number between one and five to each one of 13 questions. The obtained average is 3.8. Table 4 summarizes the results. According to question (1), most of the learners answered that it is very easy to use Sharlok. But Sharlok was slow when more than 5 participants joined the same discussion. Question (2) indicates Sharlok attracted learners, and most of them can obtain knowledge during its use. Moreover, KA did not disturb learning as the result of question (4) shows. However, it is necessary for us to improve how to provide KA.

Insert Table 4 here. (Result of questionnaire.)

Collaboration behavior

In Sharlok, the learner can start collaboration from the following options; question button (see Figure 2 (C)), passive KA, and active KA. Figure 7 (A) shows the total of requested collaboration in the test use. This figure proves clearly that collaboration is induced by KA. In particular, active KA was more effective for inducing collaboration than passive KA.

Figure 7 (B) shows the total of realized collaboration in each group. According to this figure, we can say with fair certainty that KA is very advantageous for bridging learners in a collaborative learning environment.

Insert Figure 7 here. (Collaboration behavior in each group.)

One week after doing the experimentation, we asked all the users to fill out other questionnaire about the contents of objects which they looked at, discussed or changed during the experiment. Table 2 shows the result of this questionnaire. The users could remember 44.7 % of objects which they had looked at. They have memorized 86.1 % of the object which they changed. Moreover, the learners could better remember the objects which they had discussed than the objects which they only had looked at. Hence, in order to acquire and establish new knowledge, it is more important to discuss the knowledge than to simply look at it. Therefore, active KA is a very essential function in this kind of CSCL systems.

CONCLUSION

In this paper, we proposed KA for inducing collaboration in Sharlok, an open-ended and collaborative learning system. We reached the following conclusion from the experimentation of Sharlok:

(1) In order to stabilize learners' knowledge, it is very important for learners to collaborate with each other;

(2) KA enhances collaboration opportunities in a shared knowledge space and it supports to shift from a personal learning environment to a collaborative one;

(3) Active KA is very effective for inducing collaboration between learners; and

(4) Sharlok kept learners motivated because it enhanced learners to obtain knowledge through collaboration.

In this way, we verified the effectiveness of KA. In the future, we will continue using and evaluating Sharlok.

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