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Combining Knowledge Awareness and Information Filtering in an Open-ended Collaborative Learning Environment

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Abstract. *Knowledge awareness* (KA) has been proposed to increase collaboration opportunities in an *open ended and collaborative learning environment*. To encourage collaboration, an individual user's agent called *KA-Agent* autonomously informs the learner about up-to-the-minute activities from other learners. For instance, a message might be "someone is looking at the same knowledge that you are looking at." Although this message, called *active KA*, is very useful to create real-time collaboration, a large number of messages often confuse learners and disturb their learning. Therefore, the agent has to have an *information filtering* facility to inform a learner of the important messages of KA. This paper describes a *KA filtering* technique based on some educational strategies toward efficient collaborative learning.

INTRODUCTION

Recently, researchers in the educational systems area have been attempting to provide technological support for cooperative and collaborative learning advocated by educational theories (Slavin, 1990; Webb & Palincsar, 1996; O'Malley, 1994). This paper focuses on an *open ended and collaborative learning environment*. For this situation, CoVis (Edelson et al., 1996), KIE (Linn, 1996), CSILE (Scardamalia & Bereiter, 1996), WebCamile (Guzdial et al., 1997) and Belvedere (Suthers & Jones, 1997) have been developed. CoVis focuses on making a collaboration process visible. KIE succeeds by helping students link, connect, distinguish, compare, and analyse their repertoire of ideas. 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.

An open structured CAI system, which had an extensible knowledge base, was proposed by Yano, Kashihara and McMichael (1992). As the system could acquire learner's knowledge into the knowledge base, it facilitated learner's knowledge construction which helped in increasing the learner's motivation. More likely than not, when learners acquire knowledge in the context of open-ended activities, they will use that knowledge later. Similarly, in collaborative learning, 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), a collaboration process is led by four sequential processes (Matsushita & Okada, 1995); 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 others' activities on the premise of co-presence. In the communication process, the users can exchange messages. In the final process, the user collaborates on the specific task with other users and accomplishes the task and common goals. Of these processes, awareness is very important as it starts communication and collaboration. It is very difficult for users to understand other users' activity and situation in a distant workplace.

Awareness is one of the most interesting topics, which can increase communication opportunities in a distributed workspace. Dourish and Bellotti (1992) define *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.

The following systems for supporting awareness have been developed:

1. to provide common or public space where users can gather and meet, for example, VideoWindow (Fish et al., 1992) and CRUISER (Root, 1988);
2. to give information on the surroundings of the target user, for example, Portholes (Dourish & Bly, 1992);
3. to simulate informal communicative opportunities in the real world using computers, for example, VENUS (Matsuura et al., 1995).

VideoWindow facilitates informal communication through the proposition of video images in remote sites. CRUISER simulates social browsing activity like walking around rooms. Portholes sends images every ten minutes instead of real time images, to reduce the transmission cost via the Internet. VENUS provides Interest Awareness so that a co-worker can obtain communication opportunities triggered by natural activities among remote workspaces. Although these systems are very useful for the user in understanding the activities of others in distributed places using computer and video technologies, they have not yet provided awareness for inducing collaboration in a shared knowledge space in a distributed collaborative learning situation.

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. 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 relates to 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 the 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.

Knowledge awareness (KA) has been proposed to bridge learners who are interested in the same knowledge and to create effective collaboration in a distance learning environment (Ogata et al., 1996a). 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", or "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 & 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 the learner's curiosity and that KA effectively induced collaboration between learners (Ogata & Yano, 1998). The following equation for the evaluation of KA was used.

X = No. of realized collaborations / No. of requests for collaboration.

If the learner agrees with another learner's invitation, the collaboration between them is established. The probability of realized collaborations was approximately one-and-half times higher with KA than without KA. That result showed KA was very important in realizing collaboration in real time.

In Sharlok, an individual user's agent, called *KA-Agent*, autonomously informs the learner of the up-to-the-minute activities of other learners by comparing the learner's actions with the other learners' actions. These messages are called *active KA*. However, without filtering, many messages of active KA would be provided at the same time because several learners use knowledge in the shared knowledge space. A large number of messages would disturb the learning. In this situation, information filtering technology becomes very important to aid learners' concentration. Therefore, the agent uses an *information filtering* facility to inform a learner only about the most relevant KA messages (Ogata & Yano, 1997).

The term "information filtering" refers to both finding desired information (filtering in) and eliminating that which is undesirable (filtering out). Malone et al. (1987) describes three types of information filtering approaches: content-based, social and economic. Those techniques are suitable for selecting messages, for example, e-mail and NetNews. In this paper, action based filtering toward efficient collaborative learning is proposed through comparing the learner's own curiosity with that of other learners.

An overview of Sharlok is presented in section 2 and the design of KA in section 3. Section 4 proposes active KA with intelligent information filtering. Section 5 describes how active KA can be implemented in order to support collaborative learning. Moreover, this paper describes the experimental results of active KA in section 6. Finally, the concluding remarks are given in section 7.

OVERVIEW OF SHARLOK

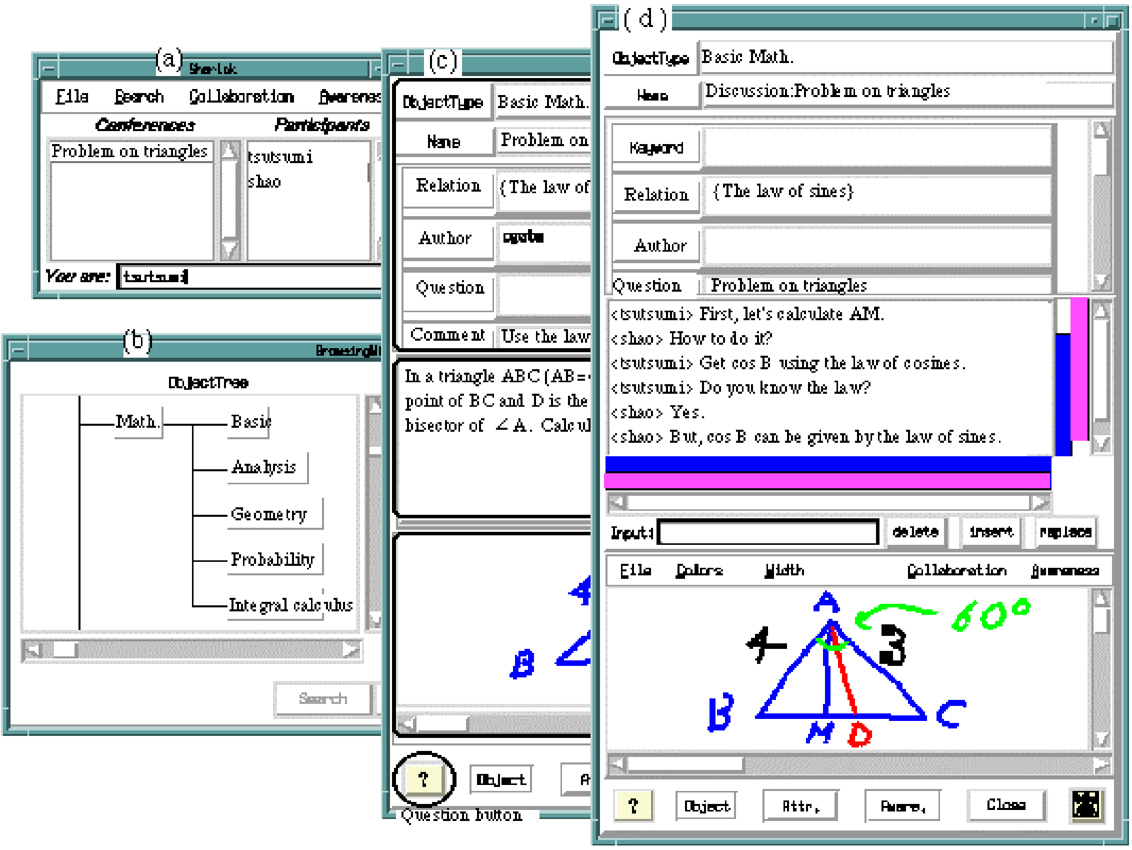

Figure 1. Screenshot of Sharlok.

Sharlok (Ogata & Yano, 1998) has an open-ended, domain-independent and collaborative learning environment connected via the Internet. The characteristics of Sharlok are as follows:

1. Sharlok provides a group notebook that allows learners to share their respective knowledge. Since Sharlok is domain-independent, a new domain may be added in Sharlok if a teacher or an administrator permits it.
2. Learners can explore the shared knowledge space according to their curiosity.
3. Learners can link between relevant knowledge as a hypertext link. By using this shared knowledge space, they can cover the multi-domain.
4. By creating or joining collaboration about the knowledge, learners can confirm or correct knowledge. Shared knowledge is refined through the collaboration.

Sharlok consists of a shared knowledge space, a collaborative environment, and knowledge awareness sub-systems. Users can respectively connect the Sharlok server from their home or office and start learning in Sharlok. The shared knowledge space is called *Holmes* (hypertext and semi-object oriented learners' memory system). Holmes enables learners to create and define a new class. Learners can create objects and input their knowledge by using pairs of attributes and values, texts and figures.

The working screen of Sharlok is shown in Figure 1. Figure 1 (a) is a starting window of Sharlok. Figure 1 (b) that is displayed form window (a) shows the hierarchy of the shared knowledge. Since Sharlok is domain independent, the domains, for example, math., computer science, composition studies, etc. are customisable by users. From window (b), the user finds the target knowledge that the user wants to learn. The knowledge is represented as Figure 1 (c). In this case, the user inputted "the problem of triangles" and he answered it. To start a discussion about this knowledge with other users of Sharlok, the "Question" button of Figure 1 (c) is used. It is difficult for the user to know what the other users are doing. There is also a problem related to selecting an adequate person who can help problem solving. Therefore, this paper proposes KA and its information filtering.

The collaborative environment in Sharlok is developed by a real time groupware system called GroupKit (Roseman & Greenberg, 1992). Without KA, the user would ask questions to all the users. Sharlok invites them to the collaboration. If a learner agrees with that, the learner becomes a participant in the collaboration. Figure 1 (a) shows the topic under discussion and its participants. The learner can join into the discussion by selecting the topic. Sharlok allows learners to communicate and collaborate in a collaboration object which includes a text chat tool, and a group drawing tool as shown in Figure 1 (d). In the text tool, the participants can write their respective ideas. Moreover, the drawing tool shows their mouse pointers and it allows them to draw figures in real time. Sharlok records the processes of the collaboration and it makes them retrievable and accessible for all the learners.

KNOWLEDGE AWARENESS

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.

There are two forms of KA in the system: "passive awareness" and "active awareness". Concerning passive awareness, the system does not show awareness information until the learner requests it. In contrast, active awareness is autonomously informed to the learner. For instance, User A may start to collaborate with User B by active KA which informs A that User B has updated the knowledge provided by User A. Hence, it is necessary to inform a learner only about the important part of knowledge in use, instead of all.

Time and knowledge proximity

As shown in Table 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.

Table 1: Types of knowledge awareness.

	Same knowledge (SK)	Different knowledge (DK)
Same time (ST)	Who is looking at the knowledge? Who is changing the knowledge? Who is discussing the knowledge?	What knowledge are they looking at? What knowledge are they changing? What knowledge are they discussing?
Different time (DT)	Who looked at the knowledge? Who changed the knowledge? Who discussed the knowledge?	What knowledge did they look at? What knowledge did they change? What knowledge did they discuss?

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.

KNOWLEDGE AWARENESS FILTERING

The goals of filtering are:

1. To sift out unacceptable KA messages that disturb learning; and
2. To give adequate priority and order KA messages according to individualised priority.

This section proposes a method by which this system recommends the appropriate KA messages for starting collaboration with a suitable learner just in time.

Taxonomy of information filtering

What kinds of viewpoints are needed to select useful information? Malone et al. (1992) classified the approaches of information filtering based on the use of The Information Lens system that allows users to sift out information with rule-based agents:

1. Content-based filtering: This approach selects documents based on the text. For example, distribution lists and simple keyword-matching techniques are used. This method is also very useful for filtering KA based on the learner's interests (curiosity) represented by keywords.
2. Social filtering: This technique selects articles based on personal and organisational interrelationships of individuals. It complements the cognitive approach by focusing on the characteristics of a message's sender, in addition to its contents. For example, the messages from the boss have high priority. In collaborative learning, the structure of the users is quite flat, compared with that of a company. Therefore, social filtering is not considered in this paper.
3. Economic filtering: This approach relies on various kinds of cost-benefit assessments and explicit or implicit pricing mechanisms. It is not clear how to apply this method in collaborative learning.
4. Collaborative filtering: This technique helps people make choices based on the opinions of other people. For example, GroupLens (Resnick et al., 1994) for the collaborative filtering of NetNews was implemented and evaluated. In collaborative learning, this approach is very effective to start collaboration with other learners who have the same interest.

Although these approaches are very useful for filtering email messages, NetNews articles, and WWW documents, they are very different from filtering messages about other activities that are informed as KA.

Factors of filtering KA

Since KA informs users of other learners' actions, this paper proposes a new concept, "***action based filtering***." This filtering approach is based on learners' activities in a collaborative learning environment. For example, learner's actions are divided into individual learning, collaborative learning, and idle. When the learner is engaged in collaborative learning, the learner does not need KA information. If the learner personally studies, the system should provide KA information according to the learner's action and interests (curiosity). If the learner does nothing, KA information might excite the learner's curiosity and it might lead the learner to collaborative learning. Table 2 shows the factors for filtering KA. These factors are quantified and these counts are combined into a composite numeric measure for ranking KA.

Table 2. Factors for filtering KA.

Filtering	Factor	Dimension
Content-based	User's interests	Uninterested ↔ Interested
Collaborative	Interests commonality	Personal ↔ Shared
Action based	Users' action	Individual ↔ Collaborative
	Other's action	Past ↔ Current

Content-based filtering of KA

This approach selects KA messages based on the learner's curiosity. We identify knowledge that interests a learner as the following:

1. Focusing knowledge:
   This knowledge is engaging the learner currently. The system can understand this case when the learner is referring, updating or talking about the knowledge.
2. Interested knowledge: This is knowledge that the learner has been interested in during the system use. The system detects the degree of interest from the number of times that the learner made specific actions: looked-at, changed, and discussed.
3. Uninterested knowledge:
   This is knowledge that the learner has no interest in or that the learner has never been aware of. This knowledge is derived from non-action of the learner.

Following the order from (1) to (3), KA messages are sorted out. In the same category, the count of actions to the knowledge is an important factor for the decision of the order.

Collaborative filtering of KA

If the learners were interested in the same knowledge, they could start collaboration easily because they have the same background. Through collaborative filtering, the system strongly recommends another learner as a good collaborator, if there are a large number of times when both the learner and the other learner have taken action to the same knowledge. For example, this filtering is very useful when a learner finds peer helpers who can help with problem solving. This system realizes this process by matching the learner's actions and the other learner's. Finally the count of collaborative filtering is combined in each category of content-based filtering.

Action-based filtering of KA

The primary role of awareness information is to make one's activity visible to others. Since learners simultaneously use some knowledge in the shared knowledge space, many messages of active KA are provided at the same time. Such messages are often an overload for learners. Therefore, a software agent, called KA-Agent, has to filter them to provide only the appropriate messages. KA messages are filtered according to learners' curiosity and their activities. KA-Agent sifts KA messages based on the following strategies:

1. Whether or not the messages disturb learning; and
2. Whether or not the messages can create effective collaboration.

There is a trade off between the provision of awareness for inducing collaboration and the preservation of individual learning. When a learner engages in learning (e.g., discussion), the messages of active KA may disturb him/her. Therefore, according to the learner's condition, we identify a way to provide KA as "direct KA" and "indirect KA" (see Table 3). If a learner is looking at or changing knowledge and another learner focuses on the same knowledge, KA-Agent directly recommends KA of type SK by using a dialogue. If the learner concentrates on learning and another learner approaches other knowledge, KA-Agent had better not display KA of type DK directly to bother the learning. Likewise, KA messages should indirectly be provided when the learner engages in discussion. This means that the system stores KA messages in an unseen list, and the learner can see the list messages after finishing the discussion if s/he wants. If the learner would be inactive (i.e., idle), then KA-Agent informs her/him KA directly about which knowledge other learners are interested in.

Table 3. Strategy for providing KA
according to learner's action and content-based filtering.

Knowledge \ Action	Collaborative learning	Indicidual learning	Inactive (Idle)
Focusing	Indirect	Direct	---
Interested	X	Indirect	Direct
Uninterested	X	X	Indirect

The KA filtering algorithm is as follows:

1. The system divides KA messages into the three categories of content-based filtering.
2. In each type, the system ranks KA messages with the measure mixed from both content-based filtering and collaborative filtering.
3. Through action based filtering, the system determines how to provide KA.

KNOWLEDGE AWARENESS FILTERING SYSTEM

KAFS (Knowledge Awareness Filtering System) has been developed in an open-ended collaborative learning environment called Sharlok. KAFS consists of an agent-based program named KA-Agent.

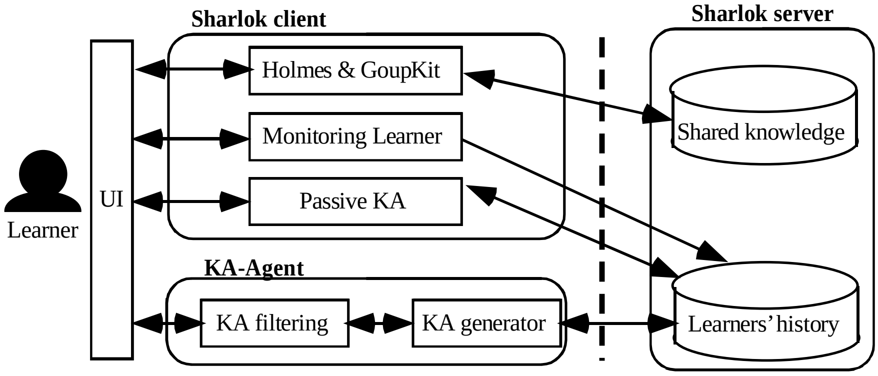

Figure2: System configuration of Sharlok & KAFS.

System configuration

As shown in Figure 2, Sharlok consists of a server, a client and an agent program, KA-Agent. The server has a shared database and a history database of learners' actions. A client consists of Holmes and GroupKit, learner-monitoring, passive KA and user interface modules. Sharlok monitors the learners' activities in the shared knowledge space (Holmes) and it stores them in the history database.

Learners' history is represented by "Who", "When", "How" and "What" attributes of 4-tuples. "Who" is the name of a learner who is doing or did actions "When" is the time and date of the action; "How" is the learner's action; and "What" is the object. These histories are recorded after operating a Sharlok interface. For example, the "changing" action is stored by pushing the save button.

There are two kinds of message in Sharlok: passive and active. Passive KA is provided using the history database with the request from the learner. This information is just the contents of the database without filtering and processing. In contrast, an active KA is autonomously generated by KA-Agent without the request from the learner. KA-Agent periodically generates KA messages based on the triggers for the display of messages. The KA generator module is continuously watching the history database. The KA filtering module achieves content-based, collaborative and action-based filtering and provides the learner with appropriate KA messages.

Figure3. Interfacce of KAFS.

Interface of passive knowledge awareness

The learner can obtain the KA after his/her request. For example, when a learner requests KA by selecting a menu, Sharlok tells him/her the information by querying the history database, as shown in Figure 3 (A). This window shows the actor (who), the beginning time of the action (when), the action (how) and the object names (what). For instance, the second item of the list in Figure 3 (A) shows Tom changed knowledge about "problem of triangle" at 96/11/17 17:06.48. These items are then sorted out by the KA-Agent. The first item is the most useful KA message for the learner. The "show obj." button displays the corresponding object to the KA message. For example, the learner can see a window like that shown in figure 1 (c) if the user selects the second item. Moreover, the learner can invite another learner for collaboration about the knowledge by selecting the "discuss" button. If the invited leaner agrees with the request for collaboration, the learner can start collaborative learning in a window like that shown in figure 1 (d).

Interface of active knowledge awareness

Based on the method of KA filtering, the KA-Agent autonomously shows the message either directly in a dialogue (see Figure 3 (C)) or indirectly in an icon (see Figure 3 (B)). Because the dialogues pop up in front of the screen, the user can see the KA messages. By pushing the icon in Figure 3 (B), the learner can obtain all of the sorted KA in Figure 3 (A). In this case, the KA-Agent provides three KA messages at the same time. The learner can customize the number of the dialogues. The learner will be able to request collaboration about "computer architectures" with "Takahasi" by using the message of Figure 3 (C). If "Takahasi" agrees with collaboration, the learner will be able to start to collaborate with her through the text chat tool and the drawing tool in the GroupKit. In this way, KA bridges each learner to create collaboration.

Implementation status

Sharlok 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 three years. Over 100 copies of the software have been distributed to other researchers and developers for demonstration purposes.

EXPERIMENTAL USE

We designed an experiment to investigate the effectiveness of KAFS.

Method

In this experiment, nine graduate students who belonged to the same laboratory participated. These students did not know our research in detail and they were interested in various computer science topics, e.g., databases, SGML, virtual reality, etc. They had already mastered how to use this system before. This time, they learned about information technologies (IT) for six days, at least four hours every day. They studied databases, information networks and computer architectures. Before the experiment, teaching materials and some questions about IT in Sharlok were prepared. The users looked at the educational information, answered the questions and discussed them. In total, they requested collaboration 1929 times and they collaborated 1248 times.

The learners used Sharlok under the following conditions. Each day they worked on a different task from one through six:

1. KA was provided without KAFS;
2. KA was provided with all the functions of KAFS;
3. KA was provided with content-based filtering;
4. KA was provided with collaborative filtering;
5. KA was provided with action-based filtering of KA; or
6. Passive KA was provided to evaluate the ranking of KA.

Experimental results

Two criteria were proposed for evaluating KAFS: the inviting rate (IR) and the realized rate (RR).

$$IR = \frac{\text{The number of requested collaboration}}{\text{The number of provided KA messages}} \times 100 \quad (1)$$

$$RR = \frac{\text{The number of realized collaboration}}{\text{The number of requested KA messages}} \times 100 \quad (2)$$

IR shows whether the learner requested collaboration from a KA message, while RR shows whether collaboration was realized after its request. The goal of KAFS is to increase the two rates.

Questionnaire

The effectiveness of KAFS was evaluated with a questionnaire. The users of Sharlok gave a number between one and five to each of ten questions, with one being the lowest, and five being the highest. The average of the points was 4.4. Table 4 shows the results of the questionnaire. According to Question (1), KA played a very important role for realizing collaborative learning. Moreover, question (2) and (3) showed KA could be provided at appropriate timing through KAFS.

Question (4) through (6) are related to the easy use of Sharlok functions. The results show that users could easily use the data input, search, and discussion functions. However, if more than ten persons use Sharlok at the same time, then the processing speed is slowed down. Therefore, the improvement of the performance is needed. From the results of question (7) and (8), we found that more new knowledge could be acquired from discussion than exploration. Through discussions, teaching other persons or learning from others was continued, and most learners replied that they had a feeling of achievements. The results of question (9) and (10) show that Sharlok was very useful for keeping learner's motivation. Most users stated that the real-time discussion was interesting.

Table 4. Results of questionnaire.

Question	Ave.
(1) Was KA very effective to enhance collaboration?	4.2
(2) Did not KA disturb your individual learning completely?	4.6
(3) Did not KA disturb your collaborative learning totally?	4.8
(4) Was data input easy?	4.1
(5) Was data search easy?	4.2
(6) Was discussion performed smoothly?	4.5
(7) Could new knowledge be acquired by exploration in shared the shared knowledge space?	3.6
(8) Could new knowledge be acquired through discussion?	4.8
(9) Was it interesting to learn with Sharlok?	4.7
(10) Did you want to continue to use Sharlok?	4.5

Content-based filtering

Content-based filtering classifies KA into focusing, interesting or uninteresting knowledge. We inspected the number of times KA messages were used through content-based filtering. Figure 4 shows the rate of collaboration based on the system's division. Focusing knowledge was used mainly because it was attractive to the learner.

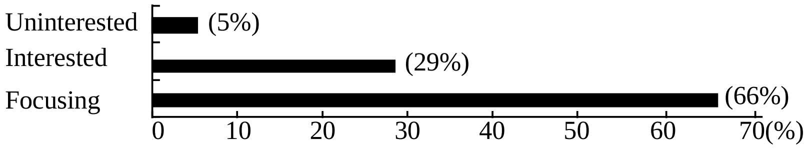

Figure 4. The rate of collaboration based on content-based filtering.

Collaborative filtering

Collaborative filtering makes a common interest high priority if both the learner and another learner are interested in the same knowledge. With the aid of collaborative filtering, learners can easily start collaboration about the knowledge. Figure 5 depicts RR based on collaboration filtering. Using this filtering, RR nearly doubled.

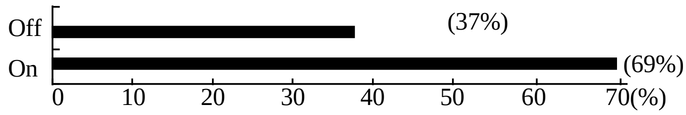

Figure 5. The realized rate of collaboration with vs. without collaborative filtering.

Action-based filtering

Action-based filtering is used to decide if KA will be provided directly or not, according to the learner's action: idle, individual learning, or collaborative learning. Figure 6 shows IR based on action-based filtering. The most collaboration was requested when the learner was inactive.

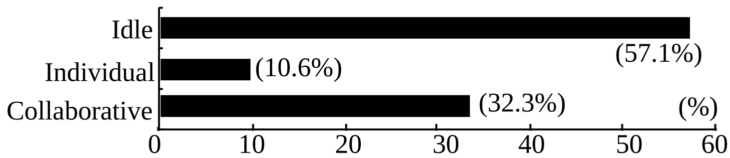

Figure 6. Action-based filtering.

KA Ranking

The validation of KA ranking was investigated, comparing its ranking when the user selected KA without KAFS. The results are presented in Figure 7. The x-axis is the message ranking made by KAFS, and the y-axis is the number of requested collaborations. The bar chart depicts real numbers, while the curve line represents an approximate value. As shown in the graph, the amount of KA use evenly declined according to the KA ranking. Therefore, it can be said that the ranking given by KAFS is valid for KA recommendation.

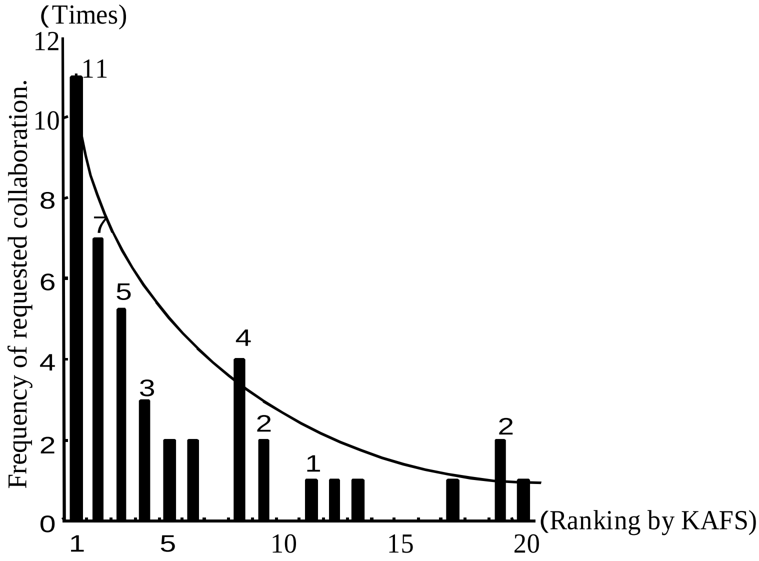

Figure 7: KA selection and its rank.

CONCLUSIONS

In this paper, a new method for filtering KA toward efficient collaborative learning was proposed. The following conclusion were reached by the test use of Sharlok:

1. KA is very effective for inducing collaboration between learners; and
2. By KA filtering, the KA-Agent could recommend the most suitable KA message and realize real-time collaboration without interfering with learning.

In the future, the use and evaluation of Sharlok and the KA-Agent will continue. In particular, a thorough investigation of the quality of collaboration mediated by the KA messages and the effect on learning outcomes using Sharlok will be undertaken. Moreover, a proposal will be made on how to recommend a suitable partner by collaboration between KA-Agents. This research addresses combining a multi-agents architecture and a CSCL issue.

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