Supporting Asynchronous Communication in an Agent-based Virtual Classroom

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Abstract. This paper describes the development and the evaluation of an asynchronous virtual classroom, named AVC, which enables learners to participate in at anytime and from anywhere. The environment has on-demand multimedia learning materials, e.g. video of the lecture, which aims at transmitting basic knowledge to learners. It also has an asynchronous communicating space among users for the purpose of enhancement, augmentation and application of the basic knowledge acquired through media materials. To utilize these two types of learning resources (i.e., on-demand materials and asynchronous communications), the system combines them effectively. Technology used in this concept allows past interactions of others to become available to the current learner. A software agent will recommend suitable interactions for the current learner according to his/her curiosity. The final part of this paper discusses the results of the experimental use of the AVC prototype.

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1   Introduction

In recent years, the conventional school-based environment has been shifting to the networked classroom. This encourages learners to build a community of spatial distributed classmates. In addition, it also has the possibility to release participants from time restrictions. This is the initial motivation for our research project named AVC (Asynchronous Virtual Classroom). The basic idea for the research has already been published in the past [1,2]. This paper proposes a simple and adaptive new method to support asynchronous dialogues among users based on their respective curiosity.

The environment of AVC system comprises some multimedia learning-materials/tools on demand. Users, including teachers and learners in this system, do not have to use this system at the same time, because the system monitors each learner's activities and reproduces them for the subsequent learners. As is often the case with these asynchronous environments, it is difficult for participants to communicate with others immediately, e.g.: Unless someone asks another person, none exists at the same time to reply. Therefore, the system bridges asynchronous participants by notifying others' activities in her/his absence at the same classroom. The system also reproduces their activities in the interface in order of relative timestamp when s/he joins the same classroom again. For example, as for the subsequent learner's activities, s/he can refer to the learning materials and join the past discussions by adding comments, asking someone to reply to her/him, making contextual branches as relevant new discussions and retrieving the past topics based on the learner's curiosity. In this way, a learner can join a virtual classroom by her/himself individually. The system provides the virtual classmates as interface agents.

Firstly, a prototype of the AVC system was developed based on this fundamental idea and evaluated several times. Through the past experimental use, a critical problem appeared in that learners sometimes felt stress at the time to read past discussions. This problem occurred often where many topics were included in one discussion room and some contexts appeared at random based on an absolute time stamp. However, this problem essentially originated from the framework itself. The AVC system synchronizes past interactions with on-demand multimedia learning materials. In other words, the system must update the contents of the past interactions with the video time flow automatically. Therefore, to tackle this problem, a new idea, which uses an adaptive support for synchronizing past interactions with on-demand learning materials based on a learner's curiosity, was used. The system sorts the stored dialogues based on a calculation of the weight of the intention of each statement in a dialogue.

Secondly, relevant works are introduced. Thirdly, an overview of the AVC concept is presented. The article in chapter four highlights the method to realize the adaptive dialogue support. Then a description of the concrete development of this method is given and close with an evaluation.

2   Related works

To apprehend the trend of interesting movement in this research area, a survey of some relevant research projects or systems was taken before describing our approach.

A large number of computer-supported classrooms are available to use for all generations in the world. They could be classified into face-to-face (FTF) type and remote one on the axis of spatial scale. The current FTF learning environments are chiefly the practical extensions of ordinary school-based classroom with up-to-date computerized facilities. For instances, Gregory and Hoppe et al. developed the

FTF system that supports computerized interactive lectures using a commercial product of a big display [3,4]. They use the system in real lectures of their own universities. Their approaches suggest a pregnant deployment with a new styled FTF lecture in a university. Essentially, their facilities could be extended to the distance lecture using video technology. One of our research aims is to support the video-based distance lecture unlike their FTF lecture support.

In the meantime, a remote classroom using computers is still classified into synchronous and asynchronous types according to the restraint that the system works under a condition for learners to participate simultaneously or not. As for a typical text-based synchronous classroom, Ogata et al. proposed a system, named Sharlok, which makes learners aware of the other learner's activities through the knowledge awareness information [5]. Seng reported the videoconference system using an MBone tool for synchronous participants to see a broadcasting video [6]. Concerned with asynchronous learning environment, Hiltz et al. established the consortium of "ALN: Asynchronous Learning Networks" [7,8]. In this consortium, they discuss several ways to realize the asynchronous extension from an ordinary FTF lecture. Motivation of the AVC project is in the partial agreement in ALN.

As the integrated environment of multimedia learning resources, Bargeron et al. reported the web based annotating environment for asynchronous collaboration among learners [9]. This system has an environment to annotate for personal and collaborative learning materials on the web. As the annotation environment is useful and strong for the asynchronous learning, the AVC system adopts a part of this. In addition to the multimedia integration on the web-based learning environment, we aim at a more interactive learning system using a software agent.

In regard to support a synchronous discussion, Hoppe et al. have developed the "Visual Language" study [10]. This study aims at visualizing and editing the structure of discussion on the shared and individual space that mainly deals with the relationship between utterances of learners. Since this study has the ability to apply both synchronous and asynchronous discussion support, our environment of supporting dialogues affords ample scope for this adoption.

The other tide of supporting interactions is in the intention-based collaborative learning environment. The Coordinator is a typical example using the Speech-Act theory in a computer system [11]. They developed the intention-based standard structure of a conversation. Many researchers adopted this concept and reported a good result to support dialogues among learners. As for the explicit dialogue supporting system, gBIS is famous for its graphical support [12]. Scardamalia & Bereiter proposed original work on the intentional learning environment whereby learners can store their opinions in the shared knowledge space [13]. Soller proposed the intelligent collaborative learning environment that promoted learners' active interaction to use a HMM model in the sentence opener of a conversation [14]. Barros & Verdejo reported an analysis for the learners' interactions process model based on the intention [15]. They proposed the dialogue structure of a small part of a conversation and the meta-level relationship of these intentional attributes, which were based on the Activity Theory [16]. A part of their intention-based idea was incorporated into this research.

The agent-oriented approach is a mainstream research area on asynchronous collaborative learning. For examples, Ayala et al. proposed a peer-tutoring agent for language learning where the agent acts were based on the settled pedagogical strategy [17]. Another example is an interface agent approach by Maes et al. for reducing information overload [18]. Our agent does not have a strong pedagogical strategy but has the function to give a presence to the current learner by displaying other learners' activities and has the added function of sifting out past interactions based on curiosity and capacity of the video time.

This research aims not only to integrate multimedia-learning resources but also to combine effectively the stable contents, which are setup by a lecturer, with dynamic contents, which are generated and updated by the participants. While many researches on supporting dialogues among learners aims to use them as a retrieval text resources, the basic idea of this research is to use them as animated resources synchronizing with the video contents.

3   Overview of Asynchronous Virtual Classroom

3.1 Design concepts

As is often the case with learners using the synchronous distance classroom, there are some constraints on participation. For example, they are forced to participate the classroom at the same time. Imposing the constraints on synchronous learning environment, they are condensed into three restrictions; simultaneous participation, limited number of the participants, and one-time participation. Meanwhile, a further aspect of the asynchronous learning environment is essentially to abolish the above restriction on the participation. By virtue of this premise, the following design concepts have been devised at the first stage of this research.

i)   Removal of a restriction on synchronous participation: The system proposes the on-demand online learning materials so that learners can participate and learn in the virtual classroom whenever they want. Learners do not have to participate simultaneously.

ii)   Over time attendee: The system proposes an alternative situation and the up-to-date contents, whenever the same learner participates in it. This prompts learners to attend the same classroom again.

iii)   No limitation on the number of participants: Owing to the delicate capacity of network and the server spec, many synchronous lecture systems reduce the number of participants. However, in many cases, the designer does not need to take into account of the reduction for an asynchronous system, because of the decrease of simultaneous participation.

3.2 Features of AVC

The transformation from text-based learning to multimedia learning can lead to great progress in various learning styles. The use of multimedia contributes not only to the increase of realistic presence but also to the promotion of interactivity among learners. In particular, video-based hypermedia environment might be usable in distance learning. Therefore, a AVC system presents multimedia contents as learning materials, which includes on-demand-video, coincident slides with sections in a video, and text-based advice from the lecturer (See table.1).

Table 1 Media as stable learning materials in AVC

Media	Explanations
Video (Streaming media)	*A video presents the animated image of real lecture. It plays a role on basis of other learning medias.*
Slide (generated by Power-Point files)	*Each slide is updated according to the video time. It is used as the supplementation of the video.*
Advice (on an applet frame)	*It is also used for supplementation. The lecturer can put the message on relative time of the lecture.*

Learning materials for each classroom must be set by the time the materials are open to the public. Although these are stable contents, a lecturer can update them at anytime according to her/his will. The system integrates additional learning materials that can be updated automatically as other learners take new actions on the system. All other learning materials; except video, are synchronized with the video's time flow. Using the stable and other synchronized materials, the envisioned effects of AVC are pointed out as follows:

a)   **Anytime/Anywhere learning:** Once a learner registers as classroom attendee, s/he can access the resources on WWW whenever s/he wants to learn.

b)   **Growing classroom:** Each classroom will grow quantitatively because the number of participants in a classroom will increase, in addition its shared knowledge space will be sophisticated qualitatively as often as the collaboration happens.

c)   **Seamless Learning:** The lecturer can link one classroom with another. Because of links based on the lecturer's intention, a learner can learn related matters and subjects.

d) **Learning by observing:** Observing the interaction among other learners and between a learner and the instructor provides an effective discussing way for the learner to be aware of various viewpoints or knowledge itself.

e) **Learning through collaboration:** The AVC system provides learners a collaboration space with others. Concrete tools include the use of a text-based bulletin board, animation of reproducing communication logs, and sharable notebook. In such an environment, a learner can refine her/his acquired knowledge through the arguments.

3.3 Agents in AVC

Agents are one of the most prominent and attractive technologies in development of a distance-learning environment. Since all participants in a lecture can be divided into two characters, a learner and a lecturer. The two types of agents that act for each owner would be developed. This section highlights the rough design of those two types of agents from the viewpoints of each action.

(1) Lecturer's agent

As in a normal face-to-face lecture, a lecturer sometimes needs supplemental explanations that make learners acquire the applied knowledge other than the basic one to be learned. Similarly, the annotation or supplemental comment to the video-based material produces a good result for learning. The agent of lecturer takes the role of supplemental explanation to main learning materials in place of the real lecturer. When the scheduled time of video arrives, an agent appears and gives a question or an auxiliary utterance to the current learner. Some actions of this agent require the reaction of the current learner and others do not. It depends on an attribute of each action that a lecturer must setup in advance. Actually, some types of allowed attributes as the reactions have been implemented. Typical reactions have been defined. For example, the first option is multiple choices whereby an agent can give the correct answer to the current learner immediately after getting the answer, and the second is a text-based inputting form that is passed on a lecturer automatically. These behaviors of agents make learners activate their learning.

(2) Learner's agent

It is effective for learners to get the reaction to her/his action immediately. This requirement leads to the development of the learner agent. The asynchronous participating environment has a feature that a learner does not notice the difference in her/his absence. The basic idea to cover the loss in the learner's absence is to show the other learner's actions by the interface agents as the virtual classmates. The specific functions for this agent activity are listed up as follows:

a) All the allowed actions of the current learner are monitored and stored on the server.

b) At the beginning of auditing, the agent of each learner checks the redundant actions at the same time in video. After this check, the agent on server sends the action data to the client in order to organize the virtual classmates. If the redundancies are found, the action filtering method adjusts them without any conflicts. The filtered out activities can be showed implicitly according to the learner's requests.

The agent can also retrieves the candidates as answers to the current learner's question. In order to find the relevant answers from the past activities, the agent retrieves the database on the server based on the keywords in the statement. If other learners participate in the same classroom semi-synchronously, the agents also mediate and ask them to answer the current learner's question. These activities between a learner and an agent will be reflected in subsequent learner's environment.

4   Supporting discussion

4.1 Interlocking dialogues with video contents

An open-ended environment has the general problem of enormous information gathering. This is caused by increases in the number of participants. In addition, the number of the arguments generated increas-

es. Many systems providing a communication tool have the functions to retrieve the outcomes, besides showing the dialogue threads stored in the past. Except for a system to deal with only static contents (e.g; gif, jpg, or txt files), a system using video image (e.g.; avi, mpg files) has a noteworthy function. It seems necessary to pay attention to treat the interlocking contents with video image.

Our approach tends to develop the application of adaptive support for discussions. We introduce a method to synchronize the dialogues with video-time based on each learner's curiosity. The system needs the indicators so that it can detect each learner's curiosity about topics in a dialogue. In order to detect the curiosity, the next section introduces the attributes of learner's intentions in a statement.

4.2 Intentions of a statement

If someone attempts an utterance, s/he would surely have the aim implicitly. However, a learner would not be conscious of the aim explicitly. There are various studies focusing on how to support these "implicit intentions". For example, Scardamalia & Bereiter have grappled originally with these intentions and developed the Computer Supported Intentional Learning Environments [14]. As another example, Reid et al. have analyzed the intention of each statement and represented them in the "Interaction Process Analysis" hierarchy [19]. Although their work has touched not only upon the attributes but also on the hierarchy of discussions, our approach focuses on only intentions as our study aims at externalizing learners' "implicit intentions" by themselves and utilizing them for subsequent learners. To sum up, our study does not have to deal with the meta-level intentions but the lowest-level ones.

As the first consideration of this work, we have classified the intentions of each learner's utterance into eight types, "theme", "conclusion", "question", "answer", "agree", "disagree", "comment", and "idle talk". Some academic simulations, which apply these intentions to the discussions of the other experimental use, were carried out. There are 3 arguments comprising 231 statements in total. Since they are non-task arguments, they do not include the "theme" and "conclusion" in the analysis. As for the other attributes of learners' intentions, we have 27 statements as "idle talks", 48 as "questions", 30 as "answer", 15 as "agree", 0 as "disagree", and 111 as "comments". These attributes seem capable of classifying the intensions of learners.

Computer-mediated conferencing systems would be used for task-oriented discussion or non-tasked free discussion. The former has the "theme" (or direction) at the beginning that is sometimes given with an educational purpose of the discussion by the teacher and "conclusion" at the end. The latter, however, does not have them explicitly because its discussion tool is used for purely interaction among learners. For that reason, the explicit difference can be seen in that the former is apt to have more statements of critical intentions than the latter one. Consequently, the system had better support discussions, especially the non-tasked free discussion, to clear the critical context with the pedagogical strategies.

The reflection of intentions is stated plainly in the interface. A learner in this system can put an intention as an attribute on each sentence by selecting one option from the list. The manipulation of text-based asynchronous discussion is different from the synchronous one (e.g., chat tool) at the point where users can afford to take enough thought of both contents and compositions to reply.

4.3 Filtering strategies

It is taken it for granted that AVC enables learners to retrieve topics from stored dialogues. The AVC system has another adaptive function whereby the system gives priority and filters dialogues based on the learner's interest in a subpart of a lecture video. The reason why we propose this function is that so many dialogues cannot display simultaneously in the animation environment at a time when many participants join the system. At the beginning of each section in a video, the calculation of a learner's interest to every dialogue is carried out as follows.

1) ***Summing up the weight of each statement in a***

Table 2 The weight of a statement

Weight	Interest	Understand
4	Theme	Conclusion
3	Question	Answer
2	Agree/Disagree	Comment
1	Idle talk	Refer
0	Nothing	

dialogue: To detect a learner's curiosity in each dialogue, the system sums up the weight of each statement in a dialogue. The weight of a statement is provided by the system according to the activities of a learner. The activities of a statement are classified into three categories; authoring, referring, and nothing. Concerning "authoring", the weight is provided as the discrete point from zero to four according to its intention. For example, "theme" and "conclusion" has the four point of weight, "question" and "answer" has the next point. As for an activity of "referring", the system counts the times to refer. "Nothing" has zero point. Furthermore, we defined that such weight of point has the types of "understanding" and "interesting". The system utilizes this type to distinguish a learner's viewpoint.

2) ***Detecting the frequency of the keywords appeared in each dialogue***: If the system cannot detect the priority by (1) method using the intention, it takes another step. The second step to detect a learner's curiosity is based on the keywords in a statement. The keywords indicate the learner's interest and the system has two types of methods for its detection. The first method is an explicit one in that the system proposes a list of keywords and a learner selects some of them. In order to list up them, a lecturer can register them before opening the classroom. The second is an implicit method in that the system detects interest words by collecting the keywords in a statement s/he inputs.

After the priority of each dialogue is detected using the above methods, the system calculates the time span for the dialogue. The dialogue will be displayed as long as the system can reproduce it for the time span of each section. Although the lower dialogues cannot be displayed in the animation window, a learner can also refer to them on another frame as the text-based threads.

5   Development

5.1 System Architecture

Figure 1 the system Architecture
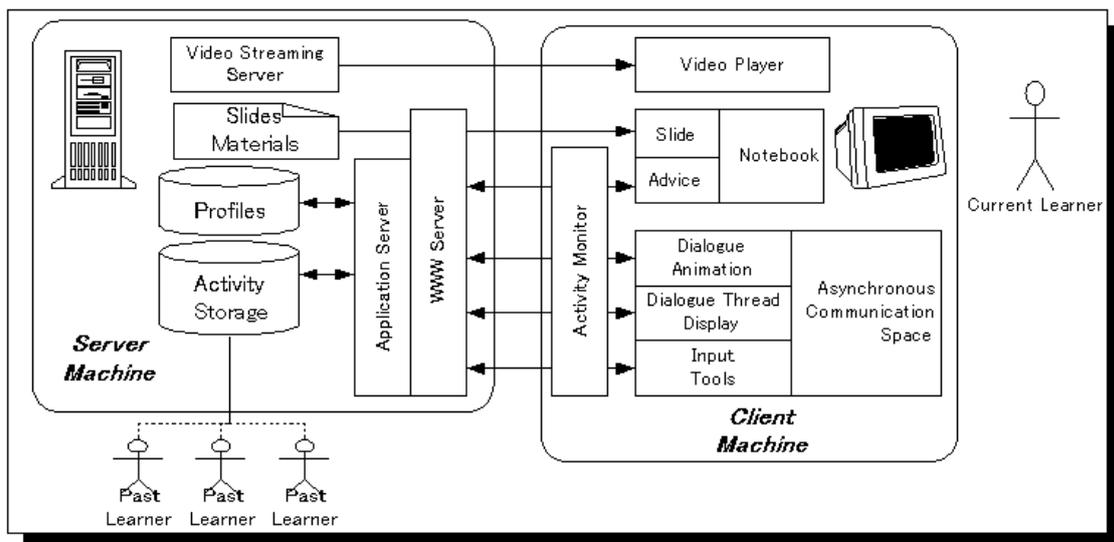
We have developed the system based on the client/server architecture. Figure 1 shows the system configuration. Client application includes three types of tools.

A) Video player: A learner watches the video contents (.asf formatted) using this tool to communicate with the streaming server.

B) Notebook: This tool, which is shown as Java applet, includes slide and advice tools. The slide images and advice are updated automatically as the video time passes. The current learner can annotate on the

slide image directly. At the end of the classroom, the system sends back the contents of annotations to the server and stores them in order to utilize them later.

C) Asynchronous Communication Tools: This tool has three subsystems; dialogue animation tool, text-based dialogue-threads tool, and the text-input tool. The dialogue animation tool displays the past interactions among learners in time order. They comply with the priority order that the system recommends. The dialogue-threads tool shows all the past dialogues with tree structure. A learner can invoke the input tool from both subsystems and input the statement with its intention, or the keyword of his/her interest.

5.2 User interface

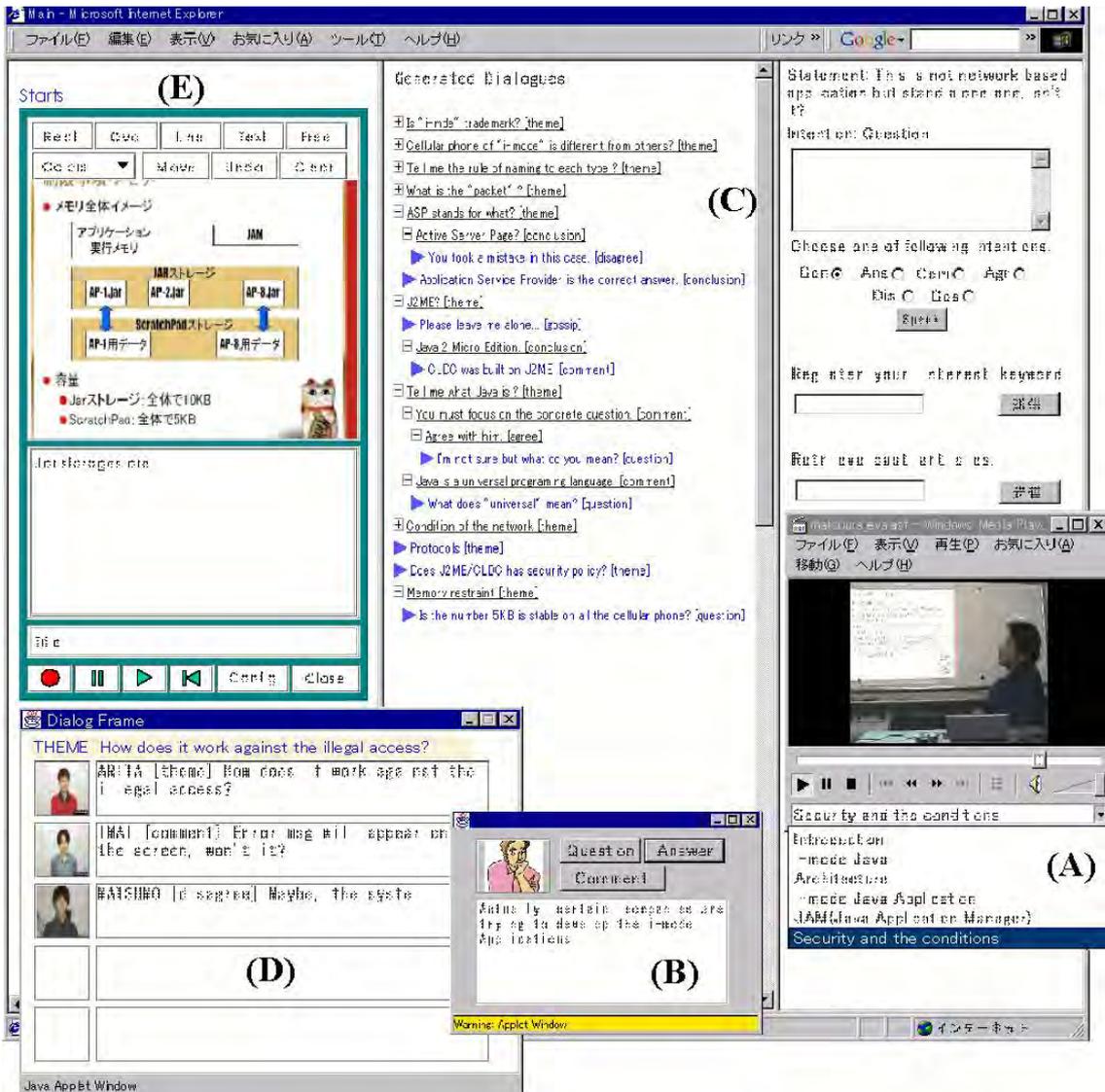**Figure 2 A snapshot of the AVC system**

Figure 2 shows the snapshot of web-based prototype. A learner can watch the streaming video in window (A), which proposes the menu of sections in a lecture. Selecting a section makes all other contents displayed in these windows update at the relative time of video. Window (B) shows the advice or quiz from lecturer. We have two types of forms to answer in (B). One is the text-based answer form that is sent to the lecturer, and the other is multiple choice of which correct answer or comment can be sent to

the learner immediately. Frame (E) shows the slide image of the lecture, in which a learner can add the annotation on it directly.

The system supports asynchronous dialogues among learners using frame (C) and window (D). A learner can see all the past dialogue threads in frame (C) with tree structure. The top node of each dialogue shows the first statement, which indicates the theme of the discussion in many cases. Since the list commands a view of the titles, a learner can select one of interesting topics and watch the dialogue in detail opening the branch. A learner can also create a new dialogue thread or add the new statement to an existing thread with its intention in the right frame of (C).

Besides the operation in frame (C), the system automatically presents the animated dialogues in window (D). On that occasion, the system sorts out the dialogues based on her/his curiosity and reproduces them in order of priority. In this window, a picture of each author of a statement is shown in the left side of the text. A learner can add the statement by clicking one of statement in (D), which is interpolated likewise the operation in frame (C). In this way, the asynchronous dialogues can be augmented.

6 Experimental Use

6.1 Method for the evaluation

To evaluate this approach, an experiment was performed for four days. The material of "CLDC libraries for developing the Java application on the cellular phone" was used as the concrete theme of the lecture for this evaluation. The video time span was about forty minutes long in total.

The users were fourteen members who were college students majoring in the information science and seemed to have interest in the theme. They were divided into the two homogeneous groups. Before we assigned the members in each group, it was determined how versed in the theme each subject was. We also needed the information of how active they were. In order to acquire the information of the ability, we compelled every subject to sit for the preliminary tests and surveyed the results. We also gave the text-based discussion system for three days before the evaluation, of which concrete equipments were text-based chat and BBS tool. Based on the number of the statements we acquired, each subject was divided into two groups so that both group had the academic ability and activity evenly.

Each group used a different system. Group A used the system A that had functions to give priorities to every dialogues in the past and to show the animated reproductions of the past dialogues in time sequence. Group B used the system B that simply reproduced the past dialogues in the time order in frame (D) of Figure 2 in section 5.2. Both systems have the function to present entire dialogues in frame (C).

Under such conditions, we compared the behaviors of learners in each group using these two types of different systems. The comparison was judged from two quantity results and a questionnaire about the impression of the whole system was sent out. As one of the former evaluations, we forced all the users to take several academic tests as the indicator for the pedagogical effect of the system. In addition to this, we report the conformity between the priority to each dialogue calculated by the system and the judgments in post questionnaires of group-A.

6.2 Remarkable results

(1) Examination
Figure 3 shows the scores of an upward curve of the scores of academic tests. Every test includes fifty questions. The horizontal axis represents the time flow of the evaluation. The number showed under the horizontal line represents the time of each test and the triangles show the time spent using the system. The vertical axis means the relative upward curve of each group-member's average scores. In order to show the pedagogical effect of the system, we set the initial score of each learner to zero and plot the relative upward score from the initial values on a graph. Learners answered to the tests with a freehand description. Learners are forced to take them before auditing of the first day and after auditing of other days. All the contents of each test are the same, including the questions of applied knowledge beyond the

video contents. In Figure 3, we find that group A reads a higher level than group B. This indicates our proposal contributes to learning.

(2) Validity of the system's recommendation
After all the experiment, we asked learners of group A to check the five-leveled curiosities to each dialogue acquired in the system. The forty-six dialogues were created by the participants. Figure 4 shows the result of conformity of the eleven ranked prominent priorities for each dialogue. Since there are some sections in a lecture video, the system calculates and gives the prior order of acquired discussions in each section. For example, if we have eleven discussions in a section, the system could give the prior order from one to eleven to each discussion. The system calculates the prior value by summing the weight on every statement in a discussion in each section. This means that the numbers of discussions in horizontal items in the figure are different. The maximum number in each item depends on the number of sections in a lecture video. As we asked learners to check the prior number to each discussion after the experiment, we can detect the conformity of learner's estimation and the system's recommendation. Four and three pointed dialogues fully agreed to the dialogues that the system gave the first priority. As its opposite result, the lower priority to the dialogues coincident to two or less points of learner's curiosities. We can find the curve of a thick line falls down to the right. This means that the dialogues' priorities of learner estimation and the system's recommendation agree highly.

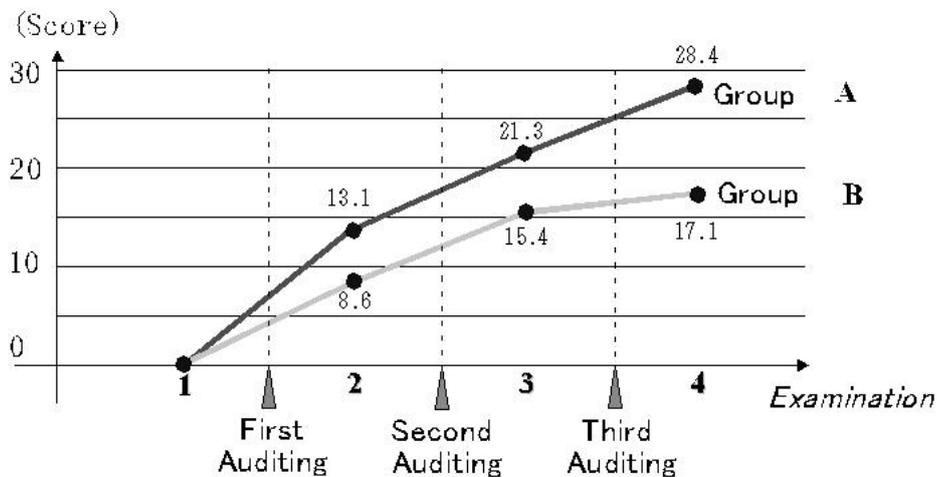**Figure 3 Ascent scores from the pretest to the posttests**

Figure 4 Conformity of the priority between learner's estimation and System's recommendation
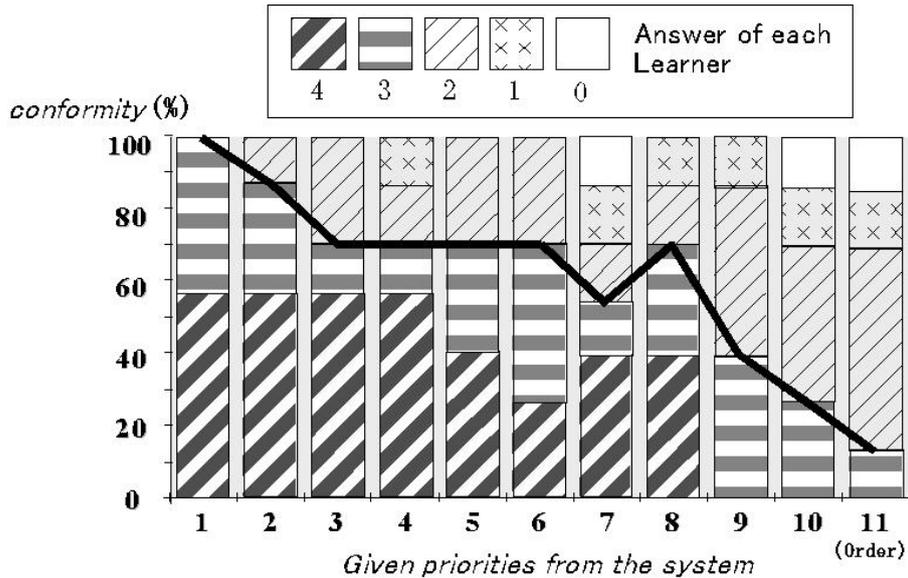
Table 3 The questionnaires

	Questionnaires	Ave. of groupA	Ave. of groupB	Ave. of total
Q1	Was the system easy to operate?	4.1	4.0	4.1
Q2	Did you feel the system available to learn?	4.0	4.1	4.1
Q3	Did you think to use this system continuously?	3.8	3.7	3.8
Q4	Did you find the interesting topics using this system?	4.3	4.0	4.2

(3) A questionnaire

To get the whole impression for learners, we forced learners to fill out a questionnaire. Table 3 shows the results of typical questions from it. The entire operability and availability of the system got higher scores (See Q1 and Q2). Nevertheless, the Q3 indicates rather low scores. We suppose more interesting functions or contents are necessary for practical use in future. The Q4 tells us our proposal was useful for asynchronous participants to find topics of interest to them.

7   Concluding Remarks

In the recent computerized society, learners no longer have to participate in a conventional school based lecture hall. They can be anytime/anywhere learners. To realize such an environment, we summarized our design policies in the former part of this paper. As a substitute for a real lecturer, the system proposes the on-demand learning materials of the lecture image, e.g. video images and slide resources. In addition to these one-way deliveries, the asynchronous communication space is necessary to acquire the applied knowledge from other participants. Hence, we introduce the interface agent to act for real learners in a same classroom. This agent reproduces the past interactions to the current learner substituting for absentees. The dialogues reproduced by the agent are sorted and appeared in the prior order of the learner's curiosity based on the explicit intention of each statement in a dialogue. They are filtered out in order to adjust the time span of every section of the lecture video.

The latter part of this paper described the evaluation of the proposal. The evaluation includes the comparative results of some academic examinations between the group-members using the system implementing our proposal and other group-members using a system without adaptive supporting dialogues. We found the former group indicated the farther upward curve of the score. In addition, the result of the system's prior order showed good agreement with the value that had been obtained by the post-questionnaire concerned with the curiosities of each dialogue. Although we evaluated this system for a

short term in that time, we will evaluate it for a long term continuously to clarify the efficiency of our approach.

Acknowledgement

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