Development of Self-Learning Support System Using Arousal Level and Lecture Information

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Summary
One of today's hot topics in an educational field is the development of efficient learning support systems. With the progress of networks and multimedia technologies, various types of web-based training (WBT) systems have been developed for distance- and self-learning. Most of the current learning support systems synchronously reproduce contents in lecture resources such as videos, slides, and digital-ink notes written by teachers. This paper describes a more efficient learning support system that provides not only multimedia data in lecture resources but also various functionalities matched to student learning level by introducing lecture information (i.e. questions/answers) and student arousal levels extracted from biological data. We also investigate the effectiveness of the proposed system through an experimental

Key words:
Self-Learning, Arousal Level, Lecture Information, Learning Support System.

1. Introduction

Many studies have been conducted focusing on the technology of learning support systems. With the progress of networks and multimedia technologies, various types of web-based training (WBT) systems have been developed for self-learning [1] [2]. The main advantage of WBT is that a student can keep his/her own pace when learning at university or at home under a network environment. On the other hand, however, some students may find it difficult to concentrate their attention on learning in an isolated environment [3] [4]; therefore, it is important for WBT how to keep the students' interest.

Most of the current support systems for web-based learning synchronously reproduce contents in lecture resources such as videos and Microsoft PowerPoint slides that a teacher uses during his/her lecture [5] [6]. These systems are very useful when confirming and/or reviewing any parts of the lecture that may have been missed. However, they do not take into consideration the attention level of the students during lectures. We have developed a multimedia lecture system with self-learning support functionalities to solve the above problem. The system will help students to review lectures more efficiently by introducing the arousal level, extracted from each student's biological data (i.e. EOG (electrooculogram), EEG (electroencephalogram), and ECG (electrocardiogram)). The multimedia lecture system provides not only multimedia contents in lecture resources but also various functionalities matched to student learning level by using the above-mentioned arousal level together with lecture information (i.e. questions/answers). Furthermore, the user interface of the proposed system is designed specifically for interactive viewing of self-learning.

2. Interactive Lecture System (ILS)

The proposed multimedia lecture system is on an individual basis and self-learning (mainly for reviewing lectures) by using each student's lecture information and biological data obtained during the lecture. The student's lecture information is acquired using the ILS (Interactive Lecture System) developed in our group [7]. Figure 1 shows an outline of the proposed system.

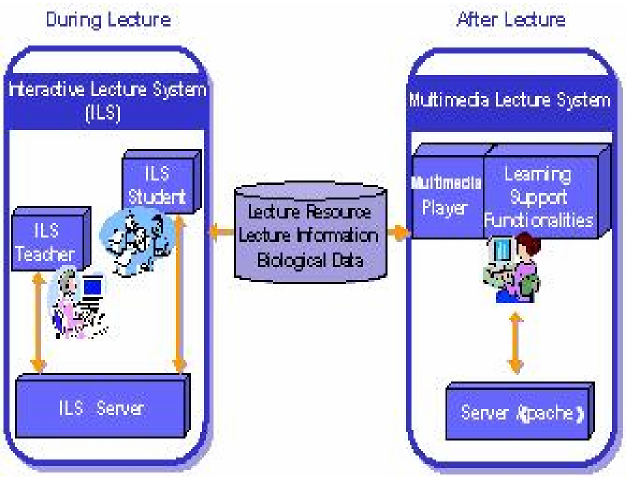

Fig. 1 Outline of the Proposed System.

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We developed a lecture support system called ILS (Interactive Lecture System) through which the students can ask questions and express their comprehensive situation during a lecture (Fig. 2). The teacher can easily determine a comprehension level from the students' reactions and subsequently ensure that his/her lecture matches the students' needs. The system is equipped with functionalities whereby the students can input their questions easily and quickly. Moreover, the system encourages the exchange of questions and answers among students using "answer promotion function" by which a student can directly send an answer to any questions from other students.

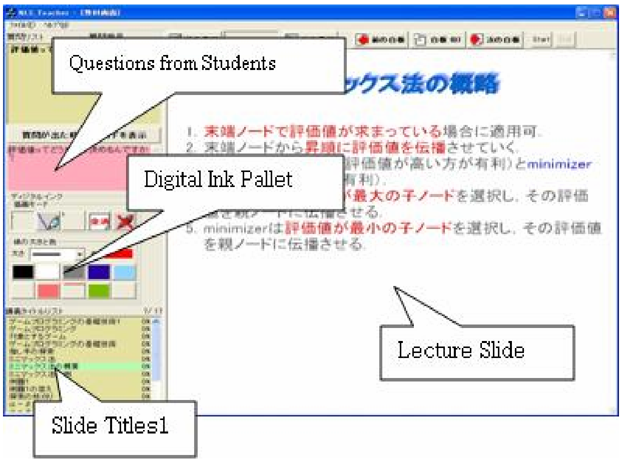


Fig. 2a Windows of ILS – teacher terminal.

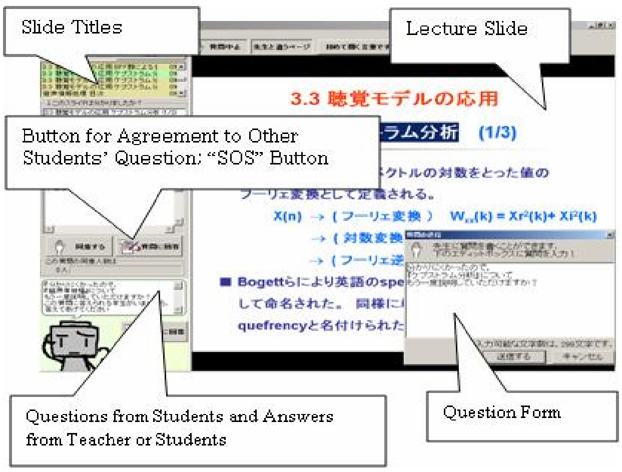


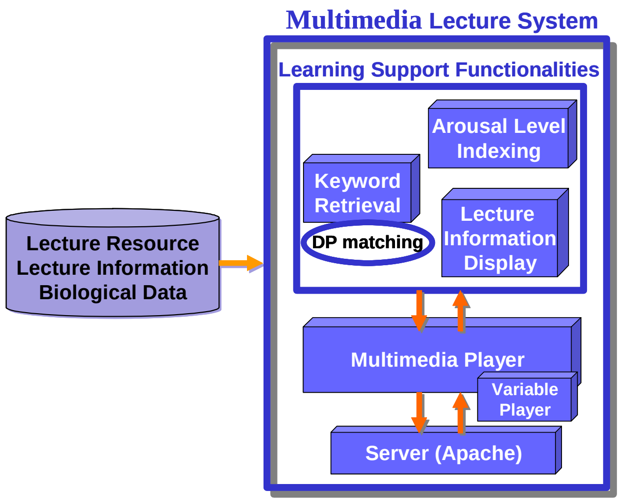
Fig. 2b Windows of ILS – student terminal.

Figure 2a and Figure 2b show ILS window of a teacher terminal and a student terminal, respectively. The system is composed of the teacher terminal, the student terminals, and a lecture server, all connected through the network. The teacher can use digital ink to freely draw lines and characters on current slide and data are sent to the student terminals through the lecture server. ILS displays the lecture resources on both the teacher and student PC terminals. When the teacher changes a slide or draws anything, the same screens are synchronously displayed on the students' PCs. When a student inputs a question using a keyboard, the question is displayed on the teacher terminal. In addition, ILS provides a function to acknowledge a question in order to collect what the students want to know in a lecture, and each question and the number of agreement to the question; that is counts from the other students' inputs using an agreement button, and displayed on the teacher terminal and the students' terminal through the lecture server. On the other hand, some students hesitate to ask questions or are unable to express a vague question in a sentence. Therefore, we added an "SOS" button on a screen of the student terminal so that students can easily tell the teacher what they want.

3. Multimedia Lecture System

This chapter describes the multimedia lecture system proposed in this paper. Figure 3 shows an outline of the system.

Fig. 3 Multimedia Lecture System; Variable Player controls play speed.



3.1 Extraction of Lecture Information and Biological Response Data

The multimedia lecture system consists of a multimedia player that reproduces the lecture faithfully, and learning support functionalities that use each student's lecture information and arousal level during the lecture (Fig. 4).

The system is designed to realize an easy-to-use, pleasant and practical-to-use self-learning.
The multimedia lecture system extracts teacher's operation data during a lecture such as lecture slide switch data, digital-ink data from the ILS. The system acquires question and the time that various events (question button, "SOS" button and acknowledgement button) occur. This data is described in XML, and is accumulated in the database. Moreover, the lecture resources that include the lecture video and slides are generated by ILS and the digital video camera and are converted into HTML.
Our group (working under a 21st Century COE Program Grant for "Intelligent Human Sensing") has developed a sensing device that extracts certain human biological information. The device is portable and includes wearable micro sensor chips. A special chair for a student to sit in with an installed sensing device has been completed and our group is presently conducting experiments using it.
In the experiments, analysis is performed on the level of arousal, understanding, and concentration by extracting biological information such as EOG (electrooculogram), EEG (electroencephalogram), and ECG (electrocardiogram) from the student listening to the lecture. The proposed multimedia lecture system uses the arousal level for biological data.

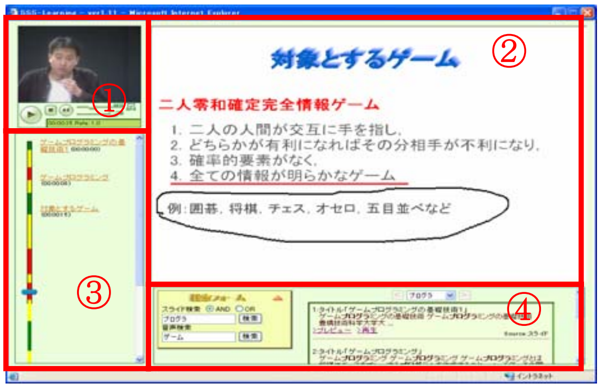


Fig. 4 Window of Multimedia Lecture System; ①Lecture Video; ② Current Slide; ③Lecture Information; ④Keyword Retrieval Box

3.2 Multimedia Player for Lecture

In the current e-learning for viewing lectures, the mainstream is to provide students lecture resources such as slides and videos on the Web. We also built the multimedia player of lectures that specifically designed for the playback of recorded classroom lecture by ILS. It synchronously displays the lecture video, and the lecture slides based on the slide switch time acquired from ILS, and the lecture is reproduced on the PC.

Students can control play speed (from half to double) and forward/backward, catching the teacher's voice clearly by using Variable Player [8] (Fig. 4①) to watch a specific part of the lecture. As a result, they can efficiently listen the lecture video. The variable-speed playback has advantages that contribute to usability.
Moreover, the slides and digital-ink notes are displayed in synchronization with the lecture video (Fig. 4②). Slide titles are also lined up along a vertical bar representing the time axis (Fig. 5). By clicking a title or sliding a handle on the bar to an arbitrary position, students can start lecture contents from the desired position. Thus, the students can learn the lecture resources in an efficient manner.
The multimedia player is implemented as a Web application by Perl/CGI and JavaScript, because students want to use it anytime, anywhere. Therefore, students can use the system any time through a Web browser under network environments.

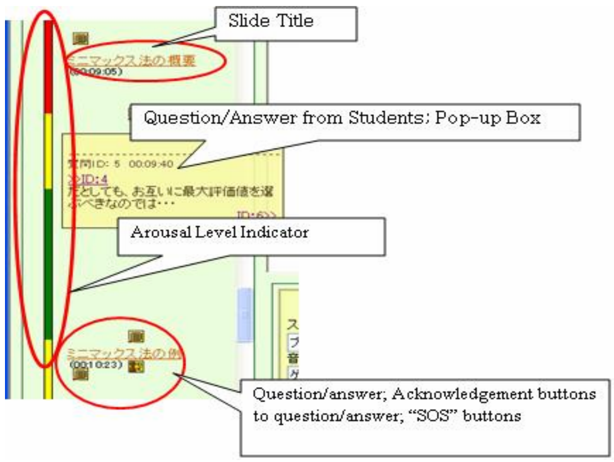


Fig. 5 Lecture Information

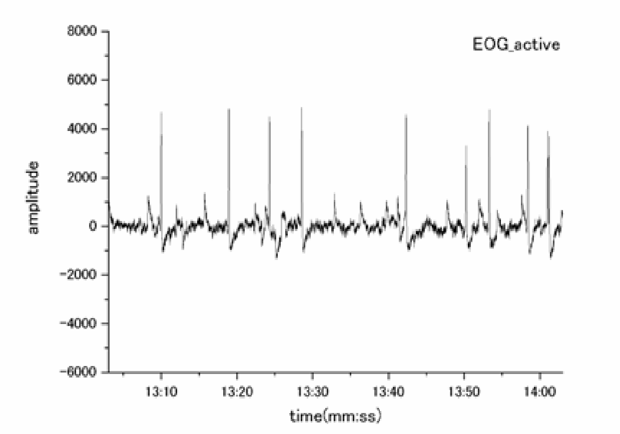


Fig.6(a) Example of the high Arousal Level: EOG data shows periodic pattern.

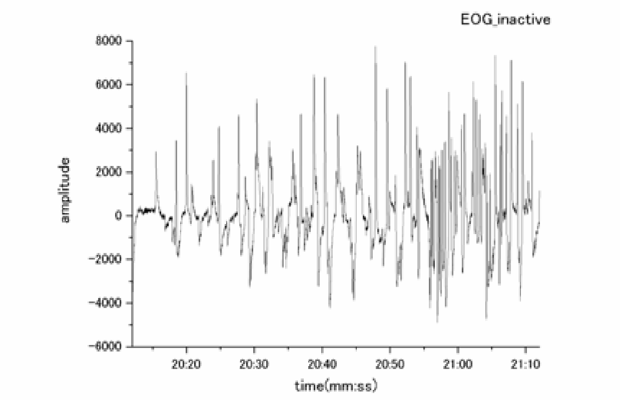


Fig.6(b) Example of the Middle Arousal Level.

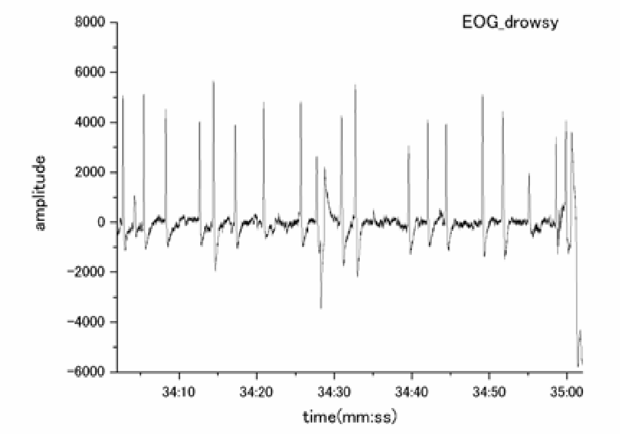


Fig.6(c) Example of the Low Arousal Level: The low amplitude is often appeared.

3.3 Learning Support Function

The multimedia player synchronously displays the lecture video and the slides, however, it is not sufficient to merely reproduce the teacher's explanation. In order to provide appropriate learning support for students, it is necessary to consider the students' states during a lecture. Therefore, our proposed multimedia lecture system contains the following three functions (Fig. 3).

(a) Utilization of Arousal Level Data

This function uses arousal level data to support students. The arousal level represents a sleeping state (low arousal level), a waking state (high arousal level), and the other state (It cannot be judged whether asleep or not) of each learner in the class. We estimate the arousal level by using correlations among some of brain wave, heart rate (ECG signal) and other bio-signal (such as breath (respiratory oscillation) and pulse wave) [9]. The arousal level is also characterized using blink duration and blink interval extracted from EOG signal [10]. Figure 6(a), Figure 6(b), Figure 6(c) show examples of the arousal level using EOG signal. For now, however, the accuracy is not still completely.

The arousal levels are distinguished by three stages, and expressed by colors of the slide bar according to the levels (Fig. 4③ and Fig. 5). A student may not have heard the lecture during low arousal level. By indexing the arousal level, he/she can efficiently find and learn missing parts. On the other hand, students presumably listen intensively the lecture when they are in the high arousal level. Therefore, the multimedia player automatically plays those parts at two or three times the speed. The students can also manually change the play speed and either fast-forward through parts where the arousal level was high or repeat parts where the arousal level was low. As a result, the students can review the lecture at a pace suitable for his/her situation efficiently and effectively.

(b) Display of Student's Lecture Information

A careful review requires lecture information that includes questions, answers or "SOS" from students; because it is important for review that the student knows own state during the lecture. Therefore, the learning support functionality provides students his/her lecture information (Fig. 4③ and Fig. 5), which consists of the following three elements acquired from the ILS.

- Question/answer
- Buttons of agreement to a question
- "SOS" buttons

When a question/answer icon is clicked, the question/answer is displayed in a pop-up box (Fig. 5). Students can press the "SOS" button when they do not understand any parts of the lecture using ILS during the lecture. They can find and investigate the factor causing the "SOS" after the lecture. Moreover, the teacher can analyze the reasons why a lot of "SOS" buttons were pressed, and then prepare additional resources to improve his/her lecture.

(c) Keyword Retrieval

One of the factors behind the difficulty of understanding at a lecture is unfamiliarity with terms appeared in teacher's explanation. Easy retrieval of those terms would be very useful when a student is reviewing the lecture. Therefore, we built a function for retrieving the lecture resources corresponding to the keywords input by the student.

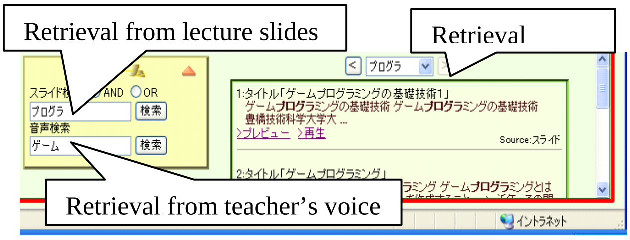


Fig. 7 Keyword Retrieval in Text and Speech Files

Our system includes not only slide retrieval but also voice retrieval (Fig. 4 ④ and Fig. 7). In the retrieval of teacher's voice, a sequence of phonemes correspond to the keyword are retrieved from the voice data by using DP matching. Because DP matching used in our system is based on the distance between distinctive phoneme feature vectors, it can detect an utterance close to the input keyword even if any parts of the phoneme sequence are substituted for similar phonemes. When the student selects a retrieval result, the lecture resources are played from the vicinity where the teacher uttered the keyword. As for retrieval of the lecture slides, the parts corresponding to the keyword input by the student from the character string in the HTML file (PowerPoint) are specified, and the slides that contain the parts are displayed as the retrieval result. In addition, the keyword retrieval that we propose gives priority to the results in order of low arousal level because the student may not have listened and understood the terms during the time that arousal level was low. As a result, the student can efficiently retrieve and learn difficult terms.

4. Experimental Evaluation

In this chapter, we describe the experiment to investigate the effectiveness of our proposed system.

4.1 Data Sets

A thirty minutes lecture on the subject of "Game Programming" is recoded using the ILS and then original lecture resources were created (original data). In the experiments, because the accuracy of arousal level extracted from biological information is not enough, we used dummy data of the arousal level. We cut out some segments (Part B in Fig.8) from the original data by using the dummy arousal level data. Namely, we regard Part B as a low-arousal-level time zone data. Each segment of Part B corresponds to the interval in which the same slide is used for the lecture. After cutting the segments (Part B), remaining segments are connected and reduced data is created (Part A). When a student sleeps during a lecture, for example, he/she is unable to listen and watch Part B lecture data. In contrast, Part A lecture data is a high-arousal-level time zone data.
For evaluation tests, we prepare five problems from Part A (Problem A), and five problems from Part B (Problem B).

4.2 Experimental Setup

To evaluate the proposed multimedia lecture system with three support functionalities, we compare the following two systems. System 1 is the proposed system.

- System 1 : multimedia lecture system (multimedia player + three support functions)
- System 2: multimedia player (only lecture video and lecture slide are given)

Seven students who did not attend the lecture "Game Programming" participated in the experiment. We divided them into Group 1 (four students) and 2 (three students). Group 1 learned the lecture using System 1, and Group 2 using System 2. The steps of the experiments were as follows:

1. We explained Group 1 and 2 how to use the systems.
2. Group 1 and 2 watch Part A.
3. Group 1 and 2 answer the Problem A(measure the response time).

Group 1 and 2 watch original data, then solve the Problem B using System 1 and 2, respectively (measure the response time).

4.3 Experimental Results

Figure 9 shows experimental results. To solve Problem A and Problem B was not a difficult task, so that most of the students were able to get 100 points. There is a significant difference of t-test between the response time for Problem A and that for Problem B. Group 1 is $P = 0.035 < 0.05$, and Group 2 is $P = 0.028 < 0.05$. It is clear that considerable time was needed to review the part where the arousal level was low. Therefore, carefully reviewing those parts of the lecture during a low arousal level leads to an efficient review of the lecture. Moreover, there is a significant difference of 106 seconds in the time taken for Group 1 and Group 2 to answer Problem B ($P = 0.136$). We can see from the results that the self-learning time for the parts during the low arousal level was reduced by using the proposed system. Therefore, it follows that the multimedia

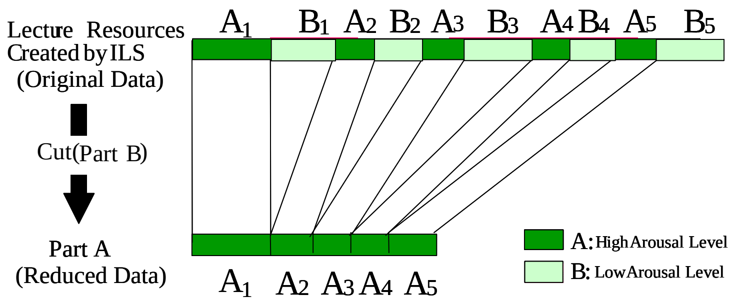


Fig. 8 Experimental Data Sets: We cut out five sections (about 2 or 3 minutes each) from original lecture resources (30 minutes), then we joined the remaining sections and reduced lecture resources (Part A) totaling about 15 minutes

lecture system is useful for an efficient and effective review. However, from a t-test point of view, there was not a significant difference between two response times for Problem B. The reason might be that the number of samples is not enough in this experiment. The further investigations are needed using enough subjects.

5. Conclusions

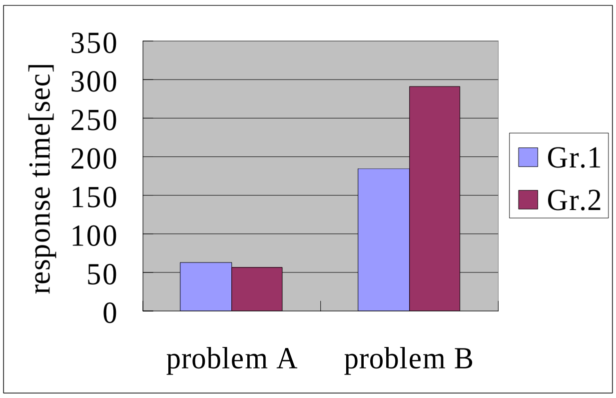


Fig. 9 Response time to problems: Gr.1 (with three support functions), Gr.2 (without three support functions) Problem A (from Part A), Problem B (from Part B).

We proposed a unique multimedia lecture system that contains three support functionalities using students' arousal level and lecture information. The experimental result using dummy arousal level data showed the effectiveness of the proposed system in which the self-learning time was remarkably improved at the low arousal level period. In our next system we will implement real arousal level data processing, and then improve the system performance more through continual self-learning tests, as well as the system user interface.

Acknowledgments

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