

A DISTANCE LEARNING SYSTEM WITH CUSTOMIZABLE SCREEN LAYOUTS FOR MULTIPLE LEARNING SITUATIONS

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Abstract: In this paper, we propose a new distance learning system that can adapt to various styles of learning activity. We assume that the system is used in distance classes with multiple live-streaming videos. Our system has functions to change the screen layout to best suit for the current learning situation for each of the participants in a class. The system also has a function to efficiently monitor the behavior of many students at a time. These functions enable us to adapt various learning activities in distance learning classes. We implemented a prototype of the proposed system and evaluated it in experimental classes. We confirmed that our system improved the activities in the experimental classes.

1 INTRODUCTION

In recent years, the development of information technologies has enabled inexpensive distance learning systems with many features, and accordingly, such systems are getting more important in higher education. With these systems, we can provide learning opportunities to remote students who have difficulties in getting to schools due to physical or geographical restrictions.

As one of the platforms for distance learning systems, a video conferencing system has been widely used. Typical video conferencing systems such as Polycom (Polycom, inc., 2010) provide high-quality video and audio communication, which enables users to obtain awareness information such as the facial expressions and gestures of remote users.

Some recent video conferencing systems focus mainly on distance learning, and they have some functions useful for distance learning activities, such as screen sharing, chat board, and response analyzer. One of the examples of this type of systems is Adobe Acrobat Connect (Adobe, inc., 2010) (referred as *Connect*, hereafter).

On the other hand, these existing systems have

the following problem. There are many situations of learning and teaching such as a lecture, practice, group work or seminar, and the situations may change quite often even during a class. However, most video conferencing systems are designed for sharing an environment with a single style; all participants share a common display layout, and the role for each participant is fixed throughout a class. This would be suitable for traditional lecture-based teaching, but not so suitable for other kinds of activities such as active learning. For example, a class may be conducted in a group work situation, in which students are divided into several groups and each group of students works independently while the teacher observes the activities of each group and gives advice as needed. In this situation, we need multiple learning environments for each group. The teacher's role in this situation is a facilitator/advisor, not a lecturer. After they finish the group activity, each group makes presentations in front of all other participants. In this situation, the presenters, who are students, have a role which is more like the lecturer, and other participants including the teacher listen to the presentations.

In this study, we assume that a computer screen is the primary user interface for distance learning, and

we focus on flexibly changing screen layouts for each participant in a class according to the current learning situation. We propose a new distance learning system that provides: (1) a mechanism that adapts the screen layout for each user according to the situation of learning and teaching, and the role of the user, such as a lecturer, listener or group member; and (2) a mechanism that helps teachers and sometimes students to monitor other students.

This paper is organized as follows. In Section 2 we present related works in the area of distance learning. In Section 3 we present a brief overview of our proposed system, and in Section 4 show the implementation of the system. In Section 5 we discuss the results of an evaluation of the proposed system in experimental classes. Finally, in Section 6 we conclude this paper.

2 RELATED WORK

Distance learning can be roughly grouped into two styles: the asynchronous style and the synchronous style. In asynchronous distance learning, students can study anytime and anywhere, using archived videos. They can communicate with teachers and classmates via e-mails and internet forums. In synchronous distance learning, participants in different places attend a class at the same time and communicate with each other in real time via video conferencing. In this study we focus on synchronous distance learning.

As we noted in Section 1, the latest distance learning systems are based on video conferencing systems (Polycom, inc., 2010; Microsoft Corp., 2010), with some additional functions for learning activities, such as text chat, screen sharing and response analysis (Adobe, inc., 2010). These systems often assume that teaching is in the traditional lecture style, in which mainly a teacher speaks and students only passively listen. Much research for distance learning systems assumes lectures in this traditional style. In (Roesler et al., 2009), the authors focus on a mechanism for efficient delivery of video and audio from the lecturer to the students. In (Shi et al., 2002), the authors propose a Smart Classroom that offers several user interfaces to facilitate lecturing activity of a teacher in distance learning, delivering proper lecturing information to remote students. But these systems are not designed for various learning situations but only for the traditional lecture style.

On the other hand, a 3D virtual environment is one of the recent approaches for distance learning (Monahan et al., 2008; Gupta and Kaiser, 2004). Some research has also used the 3D virtual environment *Sec-*

ond Life for distance learning (Ritzema and Harris, 2008; Pham et al., 2008). In a class with a 3D virtual environment, representations of all participants and the classrooms are constructed with computer graphics. The participants can communicate with each other and perform many kinds of learning activities in the virtual world. It is easy for participants to recognize the current learning situation. Visualization with 3D computer graphics enables participants to perform learning activities in ways that are similar to activities in real classes (Bouras et al., 2004a; Bouras et al., 2004b). For example, some of the participants can perform group work by making their avatars gather at a particular room in the virtual world, so that they can work independently of other participants, hiding the activities of other groups. However, some systems of this kind require a lot of operations of users, and some people may have difficulties in performing the required operations. Moreover, it is difficult to convey awareness information through 3D graphics.

The two kinds of learning methods described above, video conferencing systems and 3D virtual environments, are suitable for different situations. The differences come from differences in the information displayed on the computer screen. This implies that if the users can change the information displayed according to the learning situation, the learning system would be suitable for various learning situations. In this paper, we mainly focus on this viewpoint, and we develop a distance learning system that allows users to easily change the information displayed according to the learning situation and the roles of the users in the class.

3 THE PROPOSED SYSTEM

In this section, we describe the environment, an overview, and example use of the proposed distance learning system.

3.1 Assumed Environment

In this subsection, we explain the operating environment, the assumed learning situations, and the usage of the proposed system.

Operating Environment

We assume that one or more teachers use the proposed system at a time, and in a lecture they teach in front of a white-board or a screen while using a computer connected to the network to see a computer display on which student information is displayed. Teachers use cameras, keyboards, mice and/or microphones as input devices.

Students use computers connected to the network, and they use cameras, keyboards, mice and/or microphones as input devices when they attend a class at their home or other places.

Learning Situations

A class consists of multiple learning situations such as lectures, practice sessions, group work, and presentations. We assume that a class is conducted transitioning between multiple learning situations.

Usage of Proposed System

The proposed system provides a function to change the screen layout of each user during a class according to the learning situation.

When a teacher designs a class with the proposed system, he/she inputs the learning situations, the relationships between the situations, and screen layouts corresponding to each learning situation into the system. Once a teacher input this information, the system stores the information so that it can be used in other classes.

It is mainly the teachers who can change the screen layout to match the learning situations during a class. However, in some learning situations where students take the lead, such as group work or a presentation, students also are allowed to change the screen layout.

3.2 Overview of the System

The proposed system provides functions for (1) layout setting, (2) transition between learning situations, and (3) monitoring. Each of the functions is explained below.

3.2.1 Layout Setting

A teacher uses the layout setting function to prepare a class. With this function, a teacher can define (i) a *mode*, a state corresponding to each learning situation, (ii) a set of *roles* of users for each mode, and (iii) a screen layout used with each role.

A screen layout consists of one or more frames. A teacher can freely configure the size, position and displayed information of each frame. For example, a frame can display live video or text for practice.

3.2.2 Transition between Learning Situations

The function for transition between learning situations provides configuration and management of transitions between defined modes, changing screen layouts to match the learning situation. The proposed system displays *mode change buttons* corresponding

to each mode, and pushing a button selects the corresponding mode to start. However, if a class has many learning situations, the user may have trouble in finding the desired button. To reduce this difficulty, the proposed system displays only the buttons corresponding to modes that can be transitioned to from the current mode, based on the relationships between learning situations predefined by a teacher. This feature enables a user to quickly find the button for the next mode and to change the screen layout smoothly.

3.2.3 Monitoring

The proposed system provides a monitoring function to enable efficient monitoring of participants in a class. When many students participate in a class, a participant may not easily see the behaviors of other students through a display of a limited size. The proposed system provides functions for dynamically adjusting video size, and automatically selecting students to be displayed. With these functions, the following screen layouts can be used; (i) A layout that consists of several frames, each of which displays a student's video and changes to another students' in turn. (ii) A layout that consists of one big frame and several small frames. In the small frames, students' videos are displayed in turn. A user can choose one student to be monitored in detail and watch him/her in the big frame.

3.3 Example Use of the Proposed System

In this subsection, we show an example design of modes and screen layouts for a sample class using the proposed system. We assume that this sample class includes five learning situations which are *Lecture*, *Practice*, *Group Work*, *Question and Answer* and *Student Presentation*. Therefore, it is needed to prepare Lecture Mode, Practice Mode, Group Work Mode, Question and Answer Mode and Listening to Presentation Mode for both a teacher and a student to use the proposed system. Additionally, Student Presentation Mode is also needed as a student mode in the system.

Figure 1 and 2 show part of an example design of screen layouts for a teacher and a student in two different modes.

Figure 1 shows an example screen layout for Lecture mode. In the teacher's layout, all four video frames display students' video, each of which changes to the video of another student automatically after a certain period so that over time all students can be displayed in it. In the student's layout, the big frame displays the video of the teacher, and the other

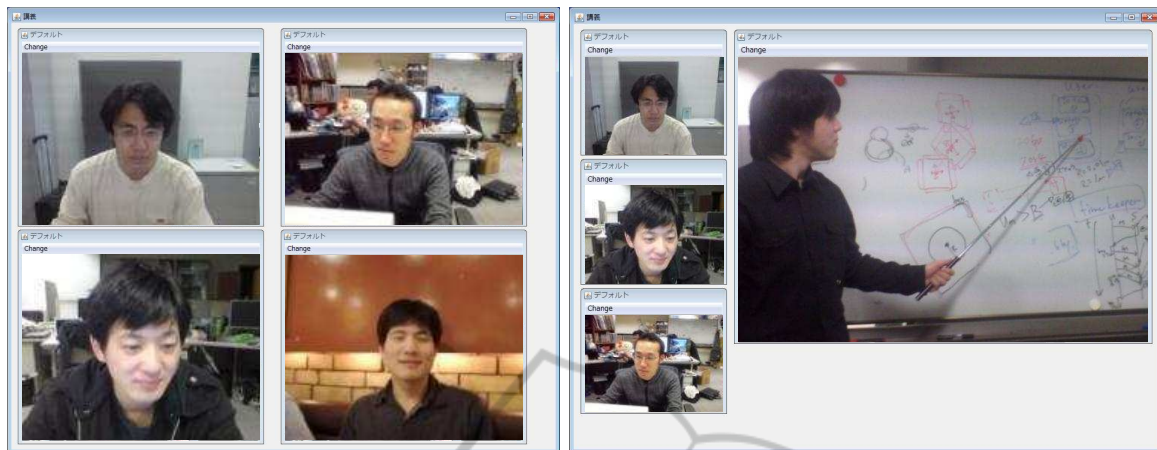


Figure 1: Screen Layout for Lecture Mode (Left: for teachers, Right: for students).

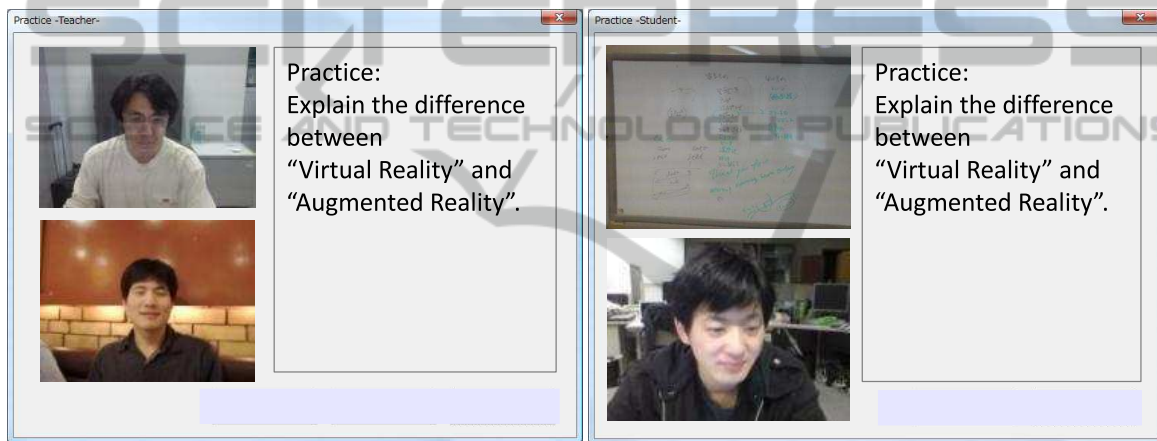


Figure 2: Screen Layout for Practice Mode (Left: for teachers, Right: for students).

three small frames display the video of other students. The video of students in the small frames also changes periodically, so that a student can watch all other participants.

Figure 2 shows a screen layout for Practice mode. Only a teacher can make the transition from Lecture mode to Practice mode. In this layout for both students and a teacher, a text about practice is displayed in the main frame. The remaining frames are different between the students and the teacher. In the layout for students, one video frame for the whiteboard and one video frame which displays students in turn are displayed on the left side. In the layout for teachers, two video frames displaying students are displayed on the left side. A teacher can stop changing displayed students and focus on a particular student at any time in this layout.

Figure 3 shows a transition graph for the class. In this class, students can transition from Lecture mode

to Question and Answer, Group Work or Practice mode, but not to Presentation or Listening mode. In the Presentation Mode, one student will be a presenter and others will be listeners. Therefore, transition from the Group Work Mode in Figure 3 can be either to Presentation Mode or Listening Mode.

The proposed system also provides a function to synchronize the modes between students and teachers. For example, if a teacher makes a transition to Lecture Mode from any neighboring mode in Figure 3, the screen layouts of all participants including all students will change to the one corresponding to the Lecture Mode.

Figure 4 is an example of the mode change buttons shown on the screen, when the current mode is Group Work mode. Following the mode transitions shown in Figure 3, only the buttons corresponding to the neighbor modes in the transition graph are shown.

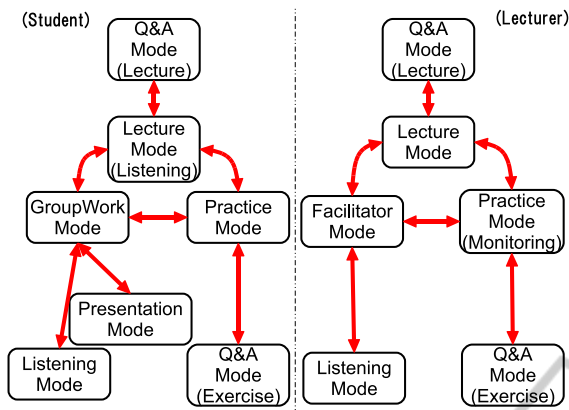


Figure 3: Transition Graph.

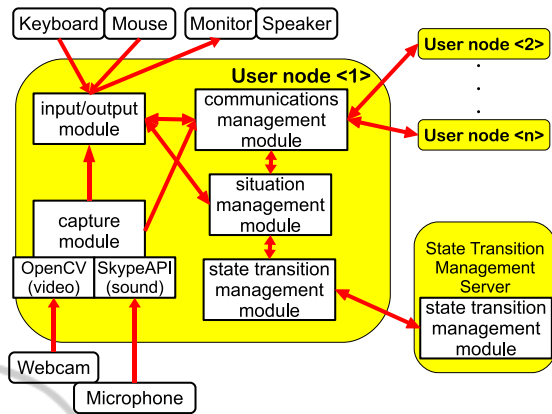


Figure 5: Architecture.

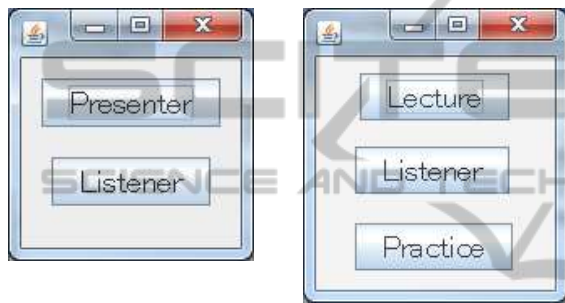


Figure 4: Mode Change Buttons in Group Work Mode (Left: for teachers, Right: for students).

4 IMPLEMENTATION OF THE PROPOSED SYSTEM

In this section, we show the internal structure and details of an implementation of the proposed system. As a trial, we used Java and OpenCV (Open Source Computer Vision Library) (Willow Garage, 2010) to implement the proposed system.

The proposed system consists of five modules as shown in Figure 5: (1) the capture module, (2) the input/output module, (3) the communications control module, (4) the situation management module, and (5) the state transition management module. The capture module deals with the video and voice of users. The input/output module controls the input from users and the output to the users. The communication control module controls the communication of video, voice, and other control information between users. The situation management module manages the information on screen layout changes caused by signals of mode change, such as pressing mode change buttons. The state transition management module maintains the state transition between modes and corresponding

screen layout for each mode.

Each module exchanges information as shown in Figure 5 where each terminal of the teacher or a student corresponds to a *user node* that executes the program containing all five modules. The state transition management module (5) also is executed at a server for coordination. In the following, we describe the detailed implementation of each module.

4.1 The Capture Module

The capture module maintains the video of users captured with a web camera and the audio of users captured with a microphone.

The video of each user is captured from a webcam via OpenCV, and then it is buffered, converted into JPEG format, and after that, sent to the input/output module and the communications control module. The audio of each user is captured from a microphone by using the Skype API (Skype4API, 2006), and then it is buffered, and after that, sent to the communication control module to provide voice communication between users.

4.2 The Input/Output Module

The input/output module consists of an input sub module that deals with input from users, and an output sub module that controls output to users.

The input sub module sends the input from keyboards, mice, etc. to the communications control module. Additionally, it sends information about mode changes to the situation management module such as clicking the mode change button. The output sub module displays video on the screen and outputs audio to the speakers. The video of the user is provided to the input/output module by the capture module and the video and the audio of other users are

provided to the input/output module by the communications control module. The video of the user and other users are displayed according to the screen layout provided by the situation management module.

4.3 The Communications Control Module

The communications control module controls the exchanges of video, audio and information about situation changes between users.

A sender user node sends the intended receiver user node information such as video and audio obtained from the capture module and the input from the mode change button obtained from the input/output module. A receiver user node sends information received from other user nodes to the input/output module and the situation management module. The modules communicate between user nodes via TCP connections.

4.4 The Situation Management Module

The situation management module manages screen layout changes. This module sends the mode change button input provided by the input/output module and mode change requests from other users provided by the communication control module to the state transition management module. Additionally, this module sends the new screen layout and modes to which the system can transition from the current mode to both input/output module and the communication control module. The information is obtained from the state transition management module.

4.5 The State Transition Management Module

The state transition management module maintains the screen layout of each mode and controls the transition between modes. A teacher should input data about the screen layout for each mode and state transition between modes before a class.

Based on the predefined state transition between modes, this module computes the modes to which the system can transit from the current mode and sends that information to the situation management module. Then, the situation management module sends information about mode change buttons to be displayed on the user's interface in the current mode to the input/output module. The mode transition is managed in a client-server style with a central state transition server for coordination purposes. This network

Table 1: Experiment 2: # of students viewed.

Exercise system	1st	2nd	3rd	4th	5th	6th
	Proposed			Connect		
Teacher 1	3	9	6	3	6	9
Teacher 2	6	3	9	3	6	9
Teacher 3	9	6	3	3	6	9

topology enables broadcast of state transition information to all user nodes without constructing a complete communication network between all user nodes.

The state transition management module has not been implemented yet. In the following experiments, the mode change buttons for all modes are displayed at each node and each mode transition is done by having all users click the mode change button for the next mode.

5 EXPERIMENTAL RESULTS

To evaluate the effectiveness of the functions of the proposed system, we conducted several experimental classes. This section provides brief overview of the experiments and results.

5.1 Overview of the Experiments

For comparison with the proposed system, we used *Adobe Acrobat Connect*. Unlike the proposed system, Connect only supports sharing one screen layout among all participants at any one time. It also displays videos of all participants in a grid layout in one frame. Finally, only the teacher can change these screen layouts. In these experiments, we used low resolution video so that we can focus on the evaluation of layout transitioning, not quality of video transmission.

We performed three types of experiments as follows:

Experiment 1. One teacher and twelve students participated in this experiment, which was aimed at testing the effectiveness of changing screen layouts for different learning situations. The students were divided into two groups of six (Group A and Group B). Each group had two classes (Class 1 and Class 2), each of which took thirty minutes; ten minutes for a lecture, five minutes for practice, five minutes for group work, and ten minutes for students' presentations about the results of the group work. Each Class had one learning topic (Class 1: User interface, Class 2: Software copyright). Group A used the proposed system in Class 1, and used Connect in Class 2. Group B used Connect in Class 1, and the proposed

Table 2: Experiment 1: impressions of the system (four-grade evaluation, 1: bad – 4: good).

		Proposed	Connect	(no answers)
Usability	(Group A)	3	3	
	(Group B)	2	3	
Understanding lectures	(Group A)	2	4	
	(Group B)	1	3	1
Observing other students (Avg.)	(Group A)	1.7	2.3	
	(Group B)	2.0	1.2	

system in Class 2. After the two classes finished, students in both groups answered a questionnaire to evaluate the effectiveness of the proposed system for their learning activity.

Experiment 2. Three teachers and nine students participated in this experiment, which was aimed at testing the effectiveness of different numbers of students being displayed. The participants performed six sets of ten minute exercises. In each exercise, the students should answer a question in ten minutes. However, some of them did other things on purpose, such as sleeping or playing with their cell phones. The teachers (Teacher 1, 2, and 3) observed the behavior of students during the exercises through the proposed system or Connect, and noted down the names of negligent students they found. For each exercise, each teacher used a different screen layout. As shown in 1, the screen layouts displayed different numbers of students. After the experiment, the teachers were asked to fill in a questionnaire to evaluate the effectiveness of different numbers of students being displayed.

Experiment 3. Six out of the nine students from Experiment 2 participated in Experiment 3, which was aimed at testing the effectiveness of the proposed system screen layouts for student presentations. For each question solved in Experiment 2, one student was chosen and made a presentation about the question and solution as a lecturer, while the other students listened to the presentation through the proposed system or Connect. The proposed system offered different layouts for a lecturer and for listeners. The lecturer used a screen layout with several video frames, each of which displayed a video of students and changed the video to that of another student periodically. Listeners used a layout with one frame displaying video of the lecturer. When they used Connect, both the lecturer and listeners watched the same screen layout that displayed videos of all participants in a grid layout. Again, participants filled in a questionnaire afterwards.

5.2 Results

Table 2 shows the results of the questionnaire for students in Experiment 1. From these results, there is no significant difference indicating that the proposed system is more useful than Connect. In fact, in evaluating the usability of the system to observe the behavior of other students in a class, Group A and Group B had opposed results. Students commented in the questionnaire that the low resolution of the video cameras and the instability of the system, both of which are not related to the changes in screen layout, were the disadvantages of the proposed system. On the other hand, they also commented that changing screen layouts to match the learning situation of a class was effective function for distance learning.

Table 3 shows the evaluation results by teachers in Experiment 2, monitoring the behavior of students through the proposed system and Connect. Again, there was no significant difference between the four-grade evaluation of the proposed system and Connect. From teachers' comments, the main disadvantage of the proposed system in this experiment also was camera resolution. On the other hand, there were several positive comments from teachers that the functions of changing the size of the video and rotating the appearance of students were effective for monitoring a lot of students.

Table 4 shows the results of the questionnaire about Experiment 3. Although the low resolution video was a disadvantage of the proposed system in the previous experiments, five out of six evaluated that monitoring the behavior of students with the proposed system was equal to or more effective than with Connect. All students also evaluated that the proposed system is superior to Connect about feeling a presence of being in a real classroom (*Feeling presence in a real classroom* in Table 4). Lecturers in Experiment 3 (Table 4 A, E and F) answered that the proposed system was effective for monitoring listeners during a presentation (*Usability of the layout for presenters* in Table 4). The functions of changing screen layouts and customizability of the layout were cited by all participants as the main reason for positive evaluation of the system.

Table 3: Experiment 2: evaluation of monitoring the behavior of students (four-grade evaluation, 1: bad – 4 :good).

Items	Teachers	3 persons / display		6 persons / display		9 persons / display	
		Proposed	Connect	Proposed	Connect	Proposed	Connect
Facial expression / gestures	A	2	3	3	3	2	3
	B	4	4	2	4	3	4
	C	4	4	3	3	3	3
	Avg.	3.33	3.67	2.67	3.33	2.67	3.33
Working situation	A	3	4	3	4	2	3
	B	3	4	3	4	4	4
	C	4	4	2	3	3	3
	Avg.	3.33	4	2.67	3.67	3	3.33

Table 4: Experiment 3: Impressions of the system (four-grade evaluation).

Questions	A	B	C	D	E	F	Avg.
Facial expressions (Proposed)	3	3	3	3	4	4	3.3
(Connect)	3	2	3	4	4	3	3.2
(1: bad – 4: good)							
Feeling presence in a real classroom	3	4	3	4	3	4	3.5
Usability of the layout for presenters (Comparison, 1: Connect – 4: Proposed)	3				3	4	3.3

5.3 Discussion

In all the experiments, the participants considered the functions of the proposed system, such as changing screen layouts and automatic or manual change of video of students, as effective approaches to understand the current situation of the class and give a feeling of being in a real classroom. These results suggest that different screen layouts are more effective for different learning situations, so adapting the screen layout to match the learning situation can contribute to better learning by distance learning students.

However, the experiments did not produce significant differences between the proposed system and Connect in quantitative terms as measured by the questionnaires. Comments by participants suggested that unimplemented functions may have affected the evaluation of the usability of the system. Future work will focus on constructing a more complete prototype and further experimentation to better evaluate the usability of the system.

Another area for future work will be to improve the resolution of the lecturer’s video. Participants in Experiment 1 and 2 commented on this as one of disadvantages of the system. However, in Experiment 2 and 3, different participants had different evaluations concerning the displays of the learning situation. These results suggest that the main problem is not how to stream high quality videos between all user nodes, but how to best customize the resolution of each video in the screen display according to the

role of the user in the learning situation and the video that the user wants to focus on.

6 CONCLUSIONS

In this paper we proposed a system supporting distance learning with multiple learning situations. We focused on enabling flexible screen layout changes, providing functions for layout setting, layout transition according to the learning situations, and efficient monitoring of participants.

From the result of the experiments to evaluate the proposed system, we confirmed that the functions for layout transition corresponding to the change of a learning situation is effective for distance learning activity, and the result would be further improved by improving the implementation of the system.

REFERENCES

- Adobe, inc. (2010). Adobe Connect for education. <http://www.adobe.com/education/products/adobe-connect.html>.
- Bouras, C., Alexiou, A., Giannaka, E., Kapoulas, V., Nani, M., and Tsiatsos, T. (2004a). The virtual radiopharmacy laboratory: A 3D simulation for distance learning. *J. of Educational Multimedia and Hypermedia*, 13(3):307–322.

- Bouras, C., Panagopoulos, A., Theoxaris, N., and Tsiatsos, T. (2004b). EVE - II: An integrated platform for networked virtual environments. In *Proc. of The 10th Int'l Conf. on Distributed Multimedia Systems (DMS 2004)*, pages 81–85.
- Gupta, S. and Kaiser, G. (2004). A virtual environment for collaborative distance learning with video synchronization. In *Proc. of the 7th IASTED Int'l Conf. on Computers and Advanced Technology in Education*, pages 16–18.
- Microsoft Corp. (2010). Live Meeting - Microsoft Office. <http://office.microsoft.com/en-gb/live-meeting/>.
- Monahan, T., McArdle, G., and Bertolotto, M. (2008). Virtual reality for collaborative e-learning. *Computers & Education*, 50(4):1339–1353.
- Pham, B., Kodama, Y., Hino, Y., Kobayashi, H., Yana, K., and Tokiwa, Y. (2008). “Second Life” as a cyber learning environment for higher education and research collaboration. In *Distance Learning and the Internet Conf. 2008*, pages 89–93.
- Polycom, inc. (2010). Polycom education solutions. <http://www.polycom.com/solutions/industry/education/>.
- Ritzema, T. and Harris, B. (2008). The use of Second Life for distance education. *J. of Computing Sciences in Colleges*, 23(6):110–116.
- Roesler, V., Husemann, R., and Costa, C. H. (2009). A new multimedia synchronous distance learning system: the IVA study case. In *Proc. of the 2009 ACM Symp. on Applied Computing (SAC 2009)*, pages 1765–1770, New York, NY, USA. ACM.
- Shi, Y., Xie, W., and Xu, G. (2002). Smart remote classroom: Creating a revolutionary real-time interactive distance learning system. In *Proc. of the 1st Int'l Conf. on Advances in Web-Based Learning (ICWL 2002)*, pages 130–141.
- Skype4API (2006). Skype API for Java. <http://skype.sourceforge.jp/>.
- Willow Garage (2010). OpenCV wiki. <http://opencv.willowgarage.com/wiki/>.