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Evaluation of Three-Site Multipoint Distance Learning using High-Definition "HyperMirror"

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Abstract: The purpose of this study is (1) to provide information about three-site multipoint distance learning utilizing the high-definition "HyperMirror" and (2) to determine how the video image quality of standard definition and high definition affect distance learning. We carried out distance learning projects twice in 2010, on (a) January 28th [Standard Definition] and (b) February 24th [High Definition], with middle schools in Nara and Kumamoto and the High Energy Accelerator Research Organization, Tsukuba in Japan. The three locations successfully connected using HyperMirror during the projects. Afterwards, a questionnaire survey revealed that image quality was not the sole contributing factor in the overall assessment of HyperMirror. However, it was suggested that easy-to-see figures, pictures, and remote students' facial expressions were important for students.

Keywords: Distance education/learning, HyperMirror, high-definition, multi-point

1. Introduction

A traditional videoconference or video chat transmits pictures that are captured by the camera for one-on-one or smaller group meetings, and the presence of another party and the atmosphere of the classroom are difficult to convey. As a solution to this, a special type of videoconferencing system called "HyperMirror" (HM) has been used successfully for distance learning. In HM, everyone appears in the same video image, in other words, everyone appears as if they are in the same room (Morikawa & Maesako, 1998). In comparison with the traditional videoconference, distance learning with HM has been confirmed to be more suitable for learning programs involving physical activities and sharing or interacting with documents/materials with the counterpart in a remote place (Imai, et al., 2002). In addition, HM proved that sharing the same space and working together virtually could make distance learning effective, despite the rather poor quality of image resolution (Matsukawa, et al., 2005).

Previous research on distance learning has shown to be of benefit of using high-definition (HD) rather than standard-definition (SD), e.g., it improved readability of text on the blackboard (Shimizu & Shiroma, 1990) and increased the feeling of high-presence distance education (Nishihara, et al., 2006)). In HM, the presented documents/materials were hard to see due to a lower-resolution format and insufficient bandwidth of the network. Therefore, HD technology was applied to HM with a wider bandwidth network, allowing a wider range of activities (Nakazawa, et al., 2009). However, whether the improvement of video image quality between SD and HD on HM affects participants' feelings has yet to be elucidated. It is possible for HM to construct more than a two-site connection, although HM has so far been done in point-to-point mode. Therefore, HM has yet to be elucidated fully concerning multipoint distance learning.

Thus, in this study, distance learning projects were conducted twice in 2010 among middle schools in Nara and Kumamoto and the High Energy Accelerator Research Organization, Tsukuba in Japan. The purpose of the research is (1) to provide information about three-site multipoint distance learning with HM and (2) to determine how the video image quality of SD and HD affect distance learning.

2. Outline of Distance Learning

2.1 Session Dates and Participants

Distance learning with HM connecting three locations was conducted on January 28, 2010, (1st session), and February 24, 2010 (2nd session). The three locations connected by HM were the High Energy Accelerator Research Organization (KEK) in Tsukuba City, Ibaragi, "N" middle school in Nara, and "M" middle school in Kumamoto. "N" middle school is located in Nara City with about 400 students in the 1st–3rd grades (equivalent to 1st–3rd grades in junior high schools). "M" middle school is located in a mountain region with about 130 enrollments in total. Two experts in "KEK" and students in Nara (1st session: 29 students; 2nd session: 20 students) and Kumamoto (1st session: 40 students; 2nd session: 15 students) participated in the distance learning.

2.2 Learning Program

As part of the outreach activities in cooperation with KEK, Center for Educational Research of Science and Mathematics, Nara University of Education develops educational programs that allow many learners to experience research on leading-edge topics in particle physics. In this exercise, instructors from these organizations and schools had examined feasible curriculums at real teaching environments and taught on the basis of those curriculums. In addition to the two distance learning sessions examined in this paper, one experimental lesson was held at each school. In the 1st session, the video quality was SD, and it consisted of three types of activities: introductions of their schools and KEK, joint classes on introductory subatomic physics taught by experts of KEK, and practical work (for N, hands-on learning in making wire chambers; for M, hands-on learning in measuring the angle of cosmic rays). In the 2nd session, the video quality was HD, and the session involved assigning follow-up tasks to each presentation, Q&A, and comments from KEK. The learning environment is the main focus of this paper, not the contents of the learning program.

3. Educational Merits of Three-Site Multipoint Distance Learning

In distance learning, practices with a traditional point-to-point videoconference such as between schools have been reported by numerous researchers. However, connecting more than two locations such as the practice here of including expert organizations and schools to carry out distance learning was unheard of. By connecting with expert organizations such as KEK, the students were able to experience and learn advanced research while being in their classrooms.

In addition, when connecting multiple locations in the traditional videoconference, every site receives numerous connected images as one combined image by connecting to the MCU (multipoint control unit). However, here we used HM so that we could more closely simulate the normal classroom environment while in a distance learning environment. With HM, it was necessary for each site to directly send and receive images reciprocally because of the need to combine images at each site. Thus, it was significant to talk about the connections when there were three connecting locations involved.

4. Network and Equipment Configuration

4.1 Network

In the two remote sessions, the three sites were connected with different networks. For the 1st session, terrestrial lines were used. Although the line installed at N school in Nara was of optical fiber, the actual bandwidth was about 1.5 Mbps and not suitable for the remote session considering the amount traffic from devices in the school. Therefore, a classroom in Nara University of Education, Japan, was hired as the venue, where the university network was used for the session (100 Mbps).

As for Kumamoto, the line used for M school was "Community Access Television" (CATV).

The line was shared with the town house and other local facilities, and while the bandwidth of M school was 5 Mbps, a preliminary test found its capacity limit at around several hundred kbps, which was barely sufficient to host a videoconference. The image transmission bandwidth for the videoconference system on the session day was fixed at around 96–384 kbps.

The second session was carried out mainly via the network under Kizuna, the ultrafast Internet satellite. Transportable antennas were set up at N and M schools to conduct communications through Kizuna. At KEK, no antenna was set up. Instead, an antenna at JAXA Tsukuba Space Center was used for communication with Kizuna. The exclusive terrestrial line connecting JAXA and KEK and the long distance wireless LAN connecting Tsukuba University and KEK were used to establish connections with Nara and Kumamoto. The connection bandwidth via Kizuna was set at approximately 17 Mbps (dual-direction) for each school and about 13 Mbps (dual-direction) for connection between JAXA Tsukuba Space Center and KEK (using the exclusive terrestrial line and a long-distance wireless LAN). The available bandwidth between each of the three locations, when connected simultaneously, was about 6 Mbps (dual-direction). As for the image transmission bandwidth during the session, the communication using the videoconference system was conducted at 4 Mbps.

4.2 Equipment Configuration

As the first session was done on SD while the second was on HD, the two sessions used different converter configurations, but the basic structures were almost the same. The following section explains the detailed structure of the learning environment, as shown in Figure 1.

First, blue screens were set up at the three locations to combine the three images through chroma key synthesis. Images from the camera of the expert standing in front of the blue screen were combined with the computer screen showing the lecture materials, and then the synthesized images were sent to Nara and Kumamoto. At the remote locations in Nara and Kumamoto, images of participants standing in front of blue screens were sent to the other two locations. Syntheses of images at one site with images received from other two locations were separately done at each location in order to minimize the impact of transmission delay. At KEK in Tsukuba, images of the expert combined with the computer screen were synthesized with images from Nara, and images from Kumamoto were finally added to create an HM of the three locations. In Nara and Kumamoto, the respective images were first synthesized with the expert's images and then combined with pictures sent from the other school.

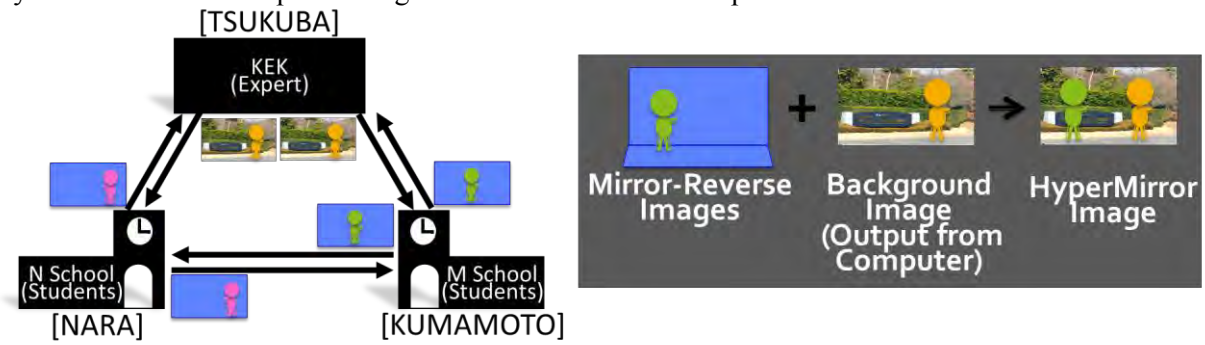

Figure 1. Simplified framework of distance learning with HM.

5. Scenes from the Distance Learning and Results of the Questionnaire Survey

5.1 Scenes from the Distance Learning

5.1.1 1st Session: HM with three locations via SD

At the first remote session, an SD network of HM connecting three locations was established. Although the resolution size was defined as SD, the network environment was limited as described before, so the image transmission bandwidth of the videoconference system was fixed at around 96 kbps between Tsukuba and Kumamoto, and 384 kbps between Tsukuba and Nara.

Figure 2 shows a scene from the actual distance learning. In this particular scene, five students

from Nara entered the picture to make a presentation. Figure 3 is the image of the expert in Tsukuba giving a lecture. The expert held a pointer with a tip in the shape of a big arrow. Figure 4 shows the PC image in Tsukuba prepared for presentation materials. The PC displayed the synthesized image made in Tsukuba featuring real-time classroom scenes of Nara and Kumamoto, which were transmitted between Tsukuba–Nara and Tsukuba–Kumamoto via video chat software. By displaying the scenes in this manner, participants were able to share the same image and learn what was going on at the other two sites. However, due to the specification limit of the video chat software, the image could not be enlarged, making the expert in Tsukuba lean in close to check the screen.

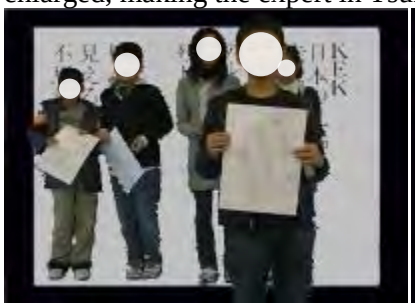

Figure 2. Students of N giving a presentation.

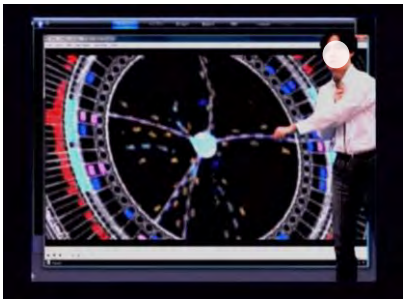

Figure 3. Expert lecturing with a background image.

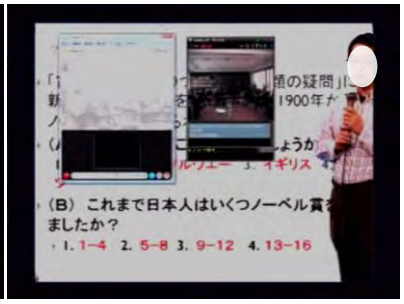

Figure 4. Real-time classroom scenes using video chats.

5.1.2 2nd Session: HM with three locations via HD

Figure 5 shows a presentation scene by students at the second remote class. In Figure 6, experts at Tsukuba were answering a question from students. Compared to the first remote session, the facial expressions were captured more clearly.

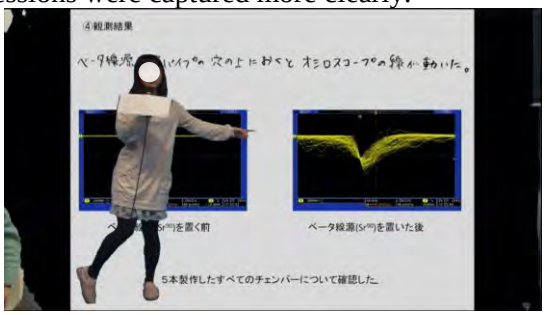

Figure 5. Students of N giving a presentation.

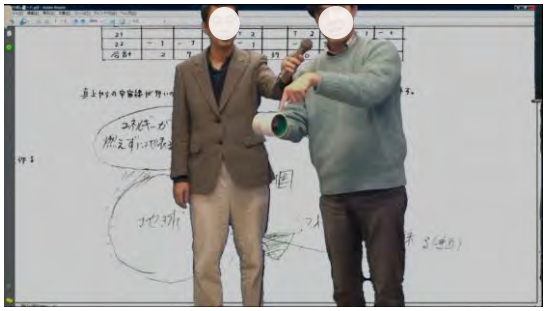

Figure 6. Experts answering the question.

5.2 Results of the Questionnaire Survey

5.2.1 Summary of Questionnaire

A questionnaire survey was conducted with students who had participated in the first and second remote classroom sessions. The questions are shown in Table 1. After each session, the questionnaire was distributed to the participating students at each school. The students answered each question by choosing one prepared answer ranging from "0: not applicable at all" to "10: very applicable." Then, in order to compare the first and second learning environments, questionnaire sheets completed by students who participated in both sessions (16 students from Nara and 15 from Kumamoto) were selected from the collected sheets to make the analysis.

5.2.2 Results

In order to find out the average value and standard deviation (S.D.) of each question, as well as to confirm the difference between the questionnaire answers from the first and second sessions, a Wilcoxon signed-rank test was conducted on each item, the result of which is shown in Table 2. According to the Wilcoxon signed-rank test result, differences were observed in Q1–Q9 at the significant level of 1%, but no significant difference manifested on Q10.

Table 1: Questionnaire and its Average, S.D.
(Wilcoxon signed-rank test results [** indicates a significance at 1%])

		Average		S.D.		V-value
		1st (SD)	2nd (HD)	1st (SD)	2nd (HD)	
Q1	I saw texts clearly.	5.14	7.45	2.76	2.29	27**
Q2	I saw figures & pictures clearly.	4.79	7.83	2.44	2.12	7**
Q3	I saw the lecturer's facial expression clearly.	4.52	7.10	2.26	2.21	28**
Q4	I saw the remote student's facial expression clearly.	3.66	7.17	2.45	2.27	3**
Q5	I knew where the remote person was pointing with a pointer or finger.	6.07	8.52	2.66	1.84	16**
Q6	The video image was natural.	4.29	6.76	2.42	2.34	25**
Q7	Was it easy to watch the video image of remote participants?	4.55	7.48	2.49	2.31	10**
Q8	I could feel the mood of the remote participants.	4.96	7.76	2.50	1.84	27**
Q9	I felt like we were in the same room.	4.62	6.62	3.16	2.51	74**
Q10	The entire HM was good.	7.59	8.41	2.58	2.01	55

6. Possibilities of HM Connecting Three Locations and Comparison of Image Quality

6.1 Possibilities of HM Connecting Three Locations

The paper examines the usability of HM connecting three locations. Past trials using HM connected only two locations, but as this paper describes, distance learning connecting three different locations facilitated by HM was also proven to be successful. By using HM, the students at Nara and Kumamoto were able to experience research and learn about particle physics with experts involved and also exchange opinions with other students and experts. Furthermore, mutual communications and learning activities occurred without major problems. Because of the synthesized presentation materials in the background, participants in the three locations were able to learn by sharing the same materials. The three-location network demonstrated in this study may be useful in carrying out distance learning activities where students of two schools hold discussions with a remotely-located expert, like in the learning session introduced here, or engage with three schools located remotely from each other.

In addition, according to the opinions of the students, regardless of the picture quality, by being able to stand next to one another in the virtual shared space and shake hands gave a sense of closeness with the partner, a feeling of reality that made it easier to ask questions and learn together.

6.2 Comparison of SD and HD

With the results of the questionnaire survey conducted with the students, this paper compares HM with SD and HD. First, as to Q1–Q7 of the questionnaire referred to image quality, there was a significant difference between SD and HD. It was clarified that HD image quality was subjectively conceived as better than that of SD. Comparing the average score of the text (Q1) and the figure and picture (Q2), there was a difference between HD and SD (as to HD, Q1 [7.45], Q2 [7.83] increased by 0.38; as to SD, Q1 [5.14], Q2 [4.79] decreased by 0.35). If the average scores of Q1 and Q2 in the case of HD were similar (i.e., if there was no difference in the ease of seeing the text and figure), this seems like a plausible explanation for the difference. But in fact, the results showed the opposite. Thus, it was presumed that students had more need to see figures and pictures than text in distance learning. Applying the same logic to facial expressions of lecturers (Q3) and students (Q4), although there was no distinct difference in the case of HD (Q3 [7.1], Q4 [7.17] increased slightly by 0.07), there was a difference in the case of SD (Q3 [4.52], Q4 [3.66] decreased by 0.86). Considering this, students paid more attention to the facial expressions of remote students than of lecturers. According to Redfern and Naughton (2012), facial expressions were an important visual cue for expressing emotion, agreement and understanding in online environments. Thus, students might deepen a sense of togetherness with the counterpart and be eager for building relationships each other, rather than the experts.

Answers to Q8 on the realistic feeling of the lecture similarly showed significant differences,

which agree with the preceding study assessing image quality in distance learning. Q9 asked about the sense of being in the same room with the remote participants. The answers for this question, again, found a significant difference between SD and HD. The same-room feeling is considered to be created by the special feature of HM. The manifestation of a significant difference in the answers to the question clarified that image quality influences the students' sense of being in the same room.

Q10 referred to the overall assessment of the HM environment. For this question, the difference between SD and HD was not significant; however, the gap between the average score was just 0.82 (Q1–Q9 of average 2.68). This fact suggests that image quality is not the sole contributing factor in the overall assessment of the HM system. Further examination is required on this matter.

7. Conclusion

In this paper, distance learning sessions with HM connecting three locations in Tsukuba, Nara, and Kumamoto were conducted with SD and HD to explore the possibility of HM connecting three locations as well as to compare SD and HD. As for HM connecting three locations, the practices with SD and HD were conducted without any problems. With HD, the image transmission bandwidth was at least 4 Mbps, and therefore, the wide and stable network was required at each location. Mutual communications and learning activities were carried out among participants as a result of multipoint HM, which made the distance learning environment close to that of a normal classroom.

According to the questionnaire, the image quality was not the sole contributing factor in the overall assessment of HM. From the result of Q10, we believe HM to be an effective system for distance learning, regardless of its picture quality. However, it was found that the participants paid attention to the graphs, pictures, and the expression of the other students. According to their free submission, the letters, pictures, and the expressions of the other person are hard to recognize with the SD image quality. Thus, in the preparation of the background image, particular attention should be paid to the size of graphs and pictures and care should be taken regarding where the participants should stand in order to maximize the quality of distance learning.

In the future, the question of what kind of educational activities are feasible or concerning videoconferences, and learning effectiveness with the image quality and further educational merits in HM connecting multiple locations shall require further study. Also, the establishment of an environment in which it is easier to set up the three-location HM is necessary. We would like to further discuss the effects of the environments described here on learning.

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