Paper

An Experiment on Multi-Video Transmission with Multipoint Tiled Display Wall

Yasuo Ebara

Central Office for Information Infrastructure, Osaka University, Osaka, Japan

Abstract—In order to realize realistic remote communication between multipoint remote places via the Internet, displaying the appearance of remote participants by transmission of a video streaming with the large-sized display system is effective. However, the display of video streaming with sufficient quality is difficult because the specification of a commercial projector and large-sized display equipment is low-resolution. In order to these issues, we focus on the tiled display wall technology which configure effective wide-area screen system with two or more LCD panels and tried to display a high-resolution video streaming on the large-scale display environment. In this paper, we have constructed remote communication environment with tiled display wall in multipoint sites and have conducted experiment in order to study the possibility of realizing realistic remote communication with multi-video streaming. As these results, these video streaming from each site have been shown to display more high-quality than magnified view of video image by a single small camera. Moreover, we have measured the network throughput performance for each transmitted and received video streaming in this environment. From measurement results, the steady throughput performance has been gained at the case of each transmitted and received video streaming.

Keywords—multipoint remote communication, tiled display wall, tele-immersion technique, video streaming.

1. Introduction

Development of information technology systems and high-speed network technology has contributed to remote communication using the Internet. Displaying the existence of remote participants by transmission of a video streaming in real scene is effective in order to conduct smooth remote communication between multipoint sites via the Internet. Currently, various software such as video phone or chat for remote communication with PC (Personal Computer) are now provided by number of users, and the demands for these software tend to increase each year [1]. However, the window size of video image in these software applications is small and low-quality. Therefore, the video image in these is difficult to display the existence of participant with sufficient image quality in remote place.

On the other hands, many high-quality video-conference systems become popular, and these are used in wide range of research and development fields. The use of large-scale display system is effective in order to conduct high-presence remote communication with video-conference system and it is considered to use display equipment such as projectors and large-sized monitors. However, the display of video streaming with sufficient quality is difficult because the specification of a commercial projector and large-sized display equipment is low-resolution.

In order to solve these issues, we focus on the tiled display wall technology which configure effective wide-area screen system with two or more LCD panels and tried to display a high-resolution video streaming on the large-scale display environment. We have showed that an ultra high-resolution video streaming with tiled display wall is effective to display the existence of participant and ambiance in remote place as a result from current experiments [2]. However, the video image captured by a single small camera is difficult to display with realistic high-resolution on a tiled display wall, because there is a limit in the display resolution of the video image captured by a single small camera.

In this paper, we have constructed a remote communication environment between multipoint sites by using tiled display wall and have conducted experiment on multi-video transmission in order to study the possibility of realizing realistic remote communication with multi-video streaming.

2. Related Works

2.1. Tele-Immersion Technique

In recent year, there has been a growing interest in tele-immersion technique because it is expected to contribute creating super realistic communication on the Internet. Tele-immersion was originally defined as the integration of audio and video conferencing, via image based modeling, with collaborative virtual reality in the context of data mining and significant computations [3]. It enables users to share a single virtual environment from different places. In the field of practical tele-immersion, it is considered necessary that everyone who is participating in the communication is able to see any part of the image transmitted from a distant place as he/she wanted [4], [5]. In the 3-D tele-immersion system, a user wears polarized glasses and a head tracker as a view-dependent scene is rendered in real-time on a large stereoscopic display in 3-D [6], [7]. Ideally, there exists a seamless continuum between the user's experience of local and remote space within the application. The communication system using the tele-immersion environment includes Tele-Cubicles [8] and 3-D video-conference system by 3-D modeling and display techniques [9]–[11].

Recently, IPT (Immersive Projection Technology) such as the CAVE system [12] has become popular, and tele-immersive virtual environments are constructed by using IPT. In addition, when several immersive projection environments have been connected through high-speed network, the real-world oriented 3-D human image is also required as a high presence communication tool between remote places [13]. In order to realize such a demand, the video avatar technology has been studied [14]. The video avatar is a technique to represent a human image with high-presence by integrating the live video image of the human into the 3-D virtual world. However, collaborative works in IPT environment requires deflection glasses and HMD. Under such conditions, carrying out smooth remote communication between participants is usually difficult.

On the other hand, we have constructed a 3-D display environment using a merged video image obtained from the multi-viewpoint videos merging system set up in the actual space [15]. The merged video image is displayed in 3-D using the auto-stereoscopic display system which does not require tools such as deflection glasses or HMD. In addition, we have examined how well two estimators can establish eye-to-eye contact with a gazer on the auto-stereoscopic display during a face-to-face communication and proved that two estimators could realize eye-to-eye contact at each direction [16]. However, we have considered that the 3-D environment is difficult to realize high-presence remote communication by the restriction of space which can move in collaborative work since the autostereoscopic display indicates an unfocused 3-D video image by participant's positions. Therefore, we consider that it is important to develop the technique to display more realistic information with simple ways for participants in order to realize high-presence remote communication.

We use tiled display wall to display high-quality video streaming which realize remote communication with highly realistic sensation. In this research, we conduct the experiment to display high-resolution video streaming on tiled display wall in multipoint sites.

2.2. Tiled Display Wall Technology

Tiled display wall is a technology to display a high-resolution image on the large-scale display with two or more LCD panels in order to construct effective wide-area screen system [17], [18]. Much research has been developed tiled display wall and remote displays by using distribute rendering technique. For example, WireGL provides the familiar OpenGL API to each node in a cluster, virtualizing multiple graphics accelerators into a sort-first parallel renderer with a parallel interface [19]. It can drive a variety of output devices, from stand-alone displays to tiled display walls. However, it has poor data scalability due to its single source limitation.

On the other hand, Chromium have designed and built a system that provides a generic mechanism for manipulating streams of graphics API commands [20]. It can be used as the underlying mechanism for any cluster-graphics algorithm by having the algorithm use OpenGL to move geometry and imagery across a network as required. In addition, Chromium's DMX extension allows execution of multiple applications and window control. Moreover, CGLX (Cross-Platform Cluster Graphic Library) is a flexible, transparent OpenGL-based graphics framework for distributed high performance visualization systems in a master-slave [21]. The framework was developed to enable OpenGL programs to be executed on visualization clusters such as a high resolution tiled display wall and to maximize the achievable performance and resolution for OpenGL-based applications on such systems. However, we assume the application of tiled display wall in remote communication environment via WAN. Therefore, we consider the use of these middleware is unsuitableness.

2.3. SAGE

In this research, we apply SAGE (Scalable Adaptive Graphics Environment) [22], [23] developed by Electronic Visualization Laboratory at the University of Illinois to delivery streaming pixel data with virtual high-resolution frame buffer number of graphical sources for tiled display wall. SAGE is a graphics streaming architecture for supporting collaborative scientific visualization environments with potentially hundreds of megapixels of contiguous display resolution. The network-centered architecture of SAGE allows collaborators to simultaneously run various applications on local or remote clusters, and share them by streaming the pixels of each application over high-speed networks to large-scale tiled display wall.

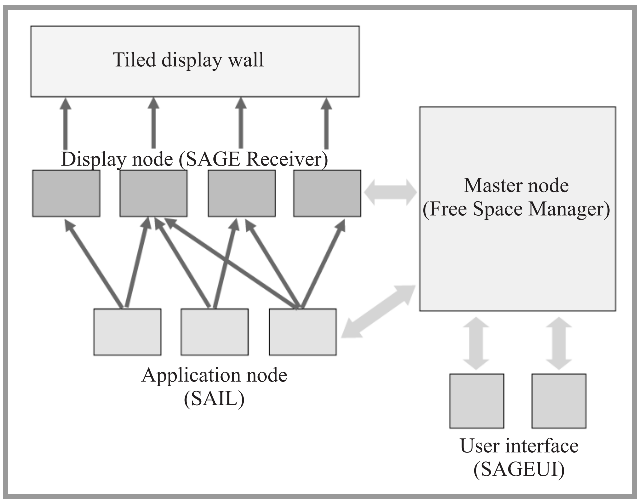


Fig. 1. SAGE components [23].

SAGE consists of the Free Space Manager, SAGE Application Interface Library (SAIL), SAGE Receiver, and User Interface (SAGEUI) as shown in Fig. 1. SAGE over WAN from SAGEUI and controls pixel streams between SAIL and the SAGE Receivers. SAIL captures application's output pixels and streams them to appropriate SAGE Receivers. A SAGE Receiver can receive multiple pixels streams from different applications and displays streamed pixels on multiple displays. A SAGE Receiver can handle multiple displays. A SAGEUI sends user commands to control the Free Space Manager and receives messages that inform users of current status of SAGE.

2.4. Multi-Video Streaming on Tiled Display Wall

We have constructed tiled display wall environment consist of 1 master node, 2 display nodes and 4 LCD panels. An example of the tiled display wall is LCDs are located at 2×2 arrays as shown in Fig. 2. Master node and all display nodes are connected by gigabit Ethernet network, and 2 LCDs are connected to 1 display node with DVI cables. In our environment, we apply SAGE as middleware of tiled display wall to delivery streaming pixel data with virtual high-resolution frame buffer number of graphical sources for tiled display wall environment.

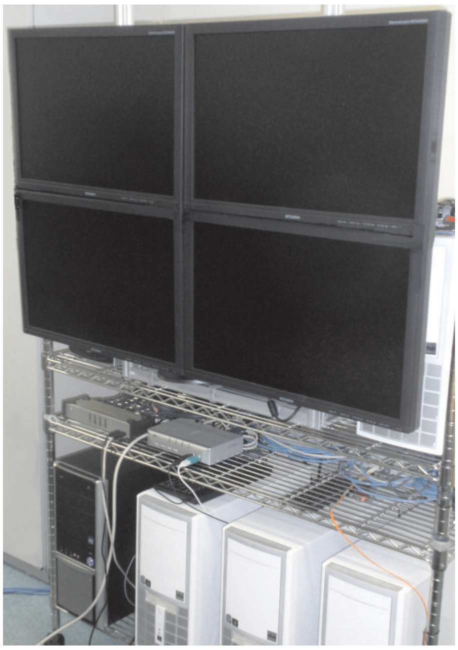


Fig. 2. Example of tiled display wall environment.

We have implemented an application of high-resolution real video streaming with a small camera by adding API code of SAIL (SAGE Application Interface Library) in source program of application. In the application, pixel information obtained from an small camera is rendered as video image by glDrawPixels on tiled display wall. The video image is captured by a small camera is transmitted from application node to master node in remote place, its video streaming is displayed on tiled display wall.

We have showed that an ultra high-resolution video streaming with a tiled display wall is effective to display the existence of participant and ambiance in remote place as a result from current experiments [2]. However, the video image captured by a single small camera is difficult to display with realistic high-resolution on a tiled display wall, because there is a limit in the display resolution of the video image captured by a single small camera. In addition, the magnified view of original video image on tiled display wall causes to degrade the quality of video image.

We have tried the construction of the environment to display realistic high-resolution video streaming on tiled display wall [24]. In this environment, each video image data which captured by multiple cameras is transmitted to display nodes of tiled display wall in remote sites from multiple application nodes via LAN. In addition, a panorama video with high-resolution which is generated by compositing these transmission video images are displayed on tiled display wall.

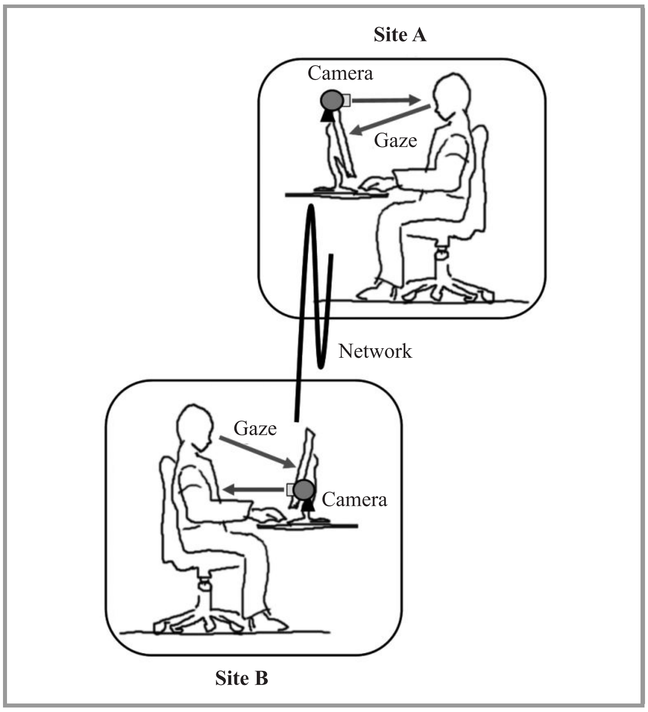


Fig. 3. Issue of eye-to-eye contact in video conference.

On the other hand, since a capturing camera which used in usual video-conference system is located at the top or both sides of display. The participant's direction of eyes often stare slides at different direction for participant of remote place. In these camera setting method, participant's direction of eyes is pointed at remote participant displayed on screen, although the setting way enable to point the camera at local participant as shown in Fig. 3. Therefore, it is difficult to have a conversation by face to face, and cause to interfere with smooth communication between participants of remote places.

In contrast, tiled display wall enables to locate freely the position of camera by using frame of LCD panel. We have conducted experiments on the possibility of eye-to-eye contact in remote communication with tiled display wall, and examined the effective location method of camera in order to solve these issues [25]. From these experiments, we have shown experimentally that each participant enables to turn direction of eyes to a camera in a natural way become important factor for realization of eye-to-eye contact in remote communication. In using these findings, we have located 2 sets of small cameras at the horizontal position on LCDs of tiled display wall to establish eye-to-eye contact naturally as shown in Fig. 4. 2 sets of Pointgray Firefly (resolution: 640×480 pixels, frame rate: 30 fps) as captured camera have been used in this environment.

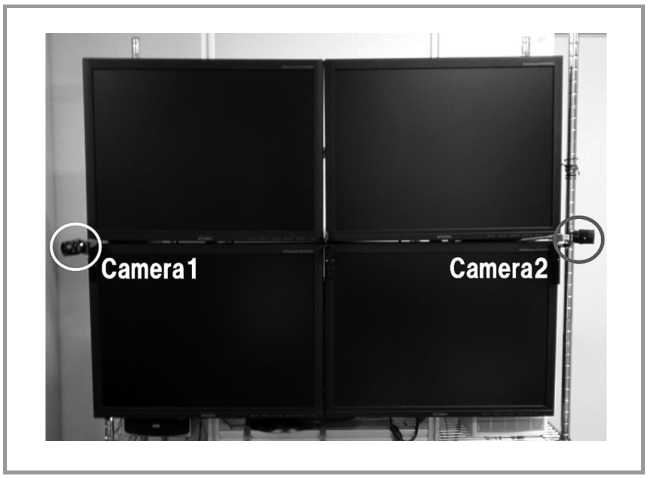


Fig. 4. Cameras setting on tiled display wall.

3. Experiment on Multi-Video Transmission in Multipoint Tiled Display Wall

3.1. Experimental Environment

In this research, we conduct fundamental experiment on the display of high-resolution video streaming on tiled display wall in each site by transmitting multi-video images which captured by multiple small cameras connected to each application node in multipoint remote sites. The network environment in this experiment is shown in Fig. 5. In this environment, 3 tiled display walls have been located in 2 network subnets. 2 tiled display walls (site A and B) in subnet 1 and 1 tiled display wall (site C) in subnet 2 have been located. Subnets 1 and 2 have been connected by L3 switch (gigabit Ethernet) in campus LAN. In each site, master node, display node, and 2 application nodes are located and connected by gigabit Ethernet with HUB (L2 switch). Table 1 shows hardware configuration of tiled display wall in each site.

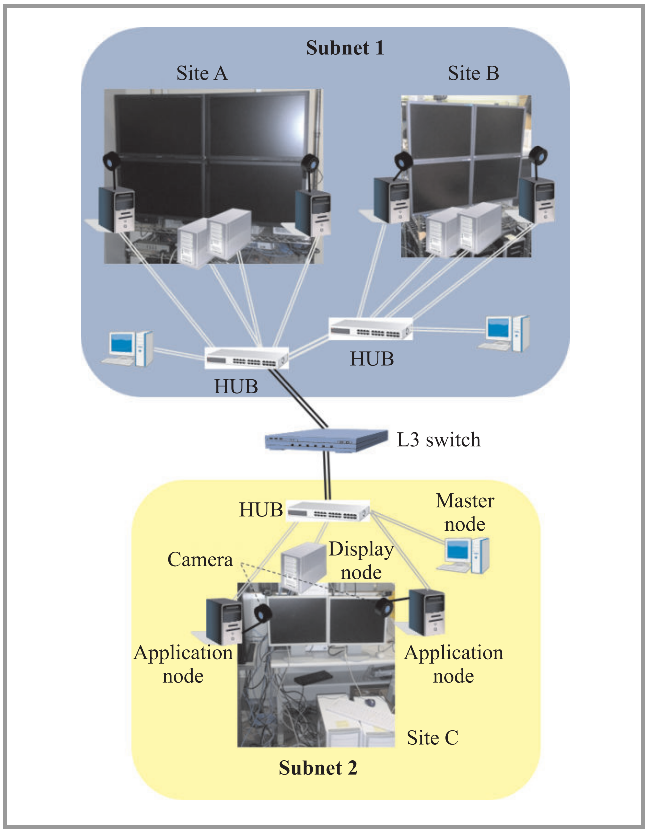


Fig. 5. Network environment between tiled display walls of 3 sites.

Figure 6 shows system configuration in this experiment. The multi-video streaming which captured by 2 cameras located at the frame of LCDs on tiled display wall in sites A, B and C are transmitted to display nodes of tiled display wall in remote sites via network from 2 application nodes of each site. In addition, a high-resolution video streaming of each site is generated by compositing these transmission video images are displayed on tiled display wall.

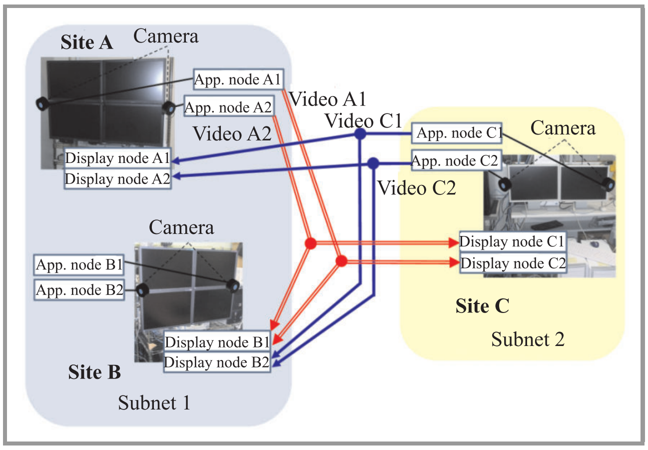


Fig. 6. System configuration in this experiment.

We have applied SAGE Bridge to realize transmission and displaying same video streaming on tiled display wall in multi-site. SAGE Bridge receives pixel streams from appli-

Table 1
Hardware configuration of each tiled display wall

	Site A	Site B	Site C
Master node			
CPU Memory VGA OS	Intel(R) Core i7 2.67 GHz 8,192 GB NVIDIA GLADIAC 786 OpenSUSE 10.3	Intel(R) Core i7 2.80 GHz 8,912 GB NVIDIA GTS 250G OpenSUSE 10.3	Intel(R) Xeon (Dual Core) 1.6 GHz (×2) 8,192 GB NVIDIA GLADIAC 786 OpenSUSE 10.3
Display node			
Number CPU Memory VGA OS	2 Intel(R) Core i7 2.93 GHz 8,192 GB NVIDIA GTS 250G OpenSUSE 10.3	2 Intel(R) Core i7 2.93 GHz 4,096 GB NVIDIA GTS 250G OpenSUSE 10.3	1 Intel(R) Core i7 2.80 GHz 4,096 GB NVIDIA Quadro FX 570 OpenSUSE 10.3
Application node			
CPU Memory VGA OS	Intel(R) Core i7 2.80 GHz 4,096 GB NVIDIA Quadro FX 570 OpenSUSE 10.3	Intel(R) Core i7 2.80 GHz 4,096 GB NVIDIA Quadro FX 570 OpenSUSE 10.3	Intel(R) Core i7 2.80 GHz 4,096 GB NVIDIA Quadro FX 570 OpenSUSE 10.3
LCD panel			
Number Size Resolution	4 24.1 inch 1,920×1,200	4 17 inch 1,280×1,024	2 17 inch 1,280×1,024

cations and distributes to multiple SAGE sessions and is supposed to be executed on high-performance PCs bridging rendering clusters and display clusters [26]. In this experiment, all application nodes are used as SAGE Bridge node, and are transmitted multi-video streaming to tiled display walls in multiple remote sites via LAN.

3.2. Experimental Results

Multi-video streaming of each site which generated by compositing transmission video captured by 2 sets of small cameras in sites A and C are displayed on tiled display wall in site B as shown in Fig. 7. From these results, we consider that these video streaming from each site have

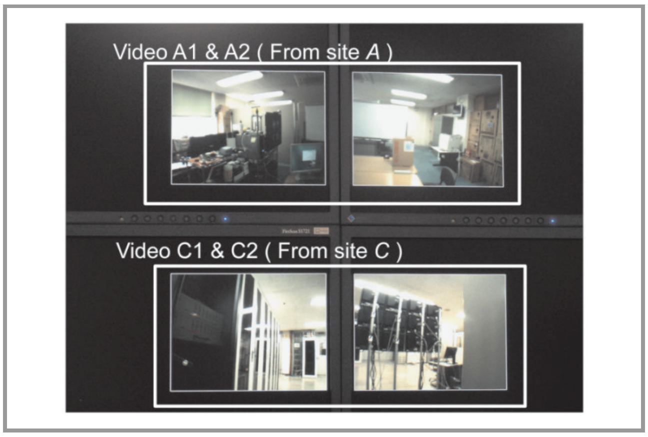


Fig. 7. Display result of multi-transmission video image on tiled display wall in site B.

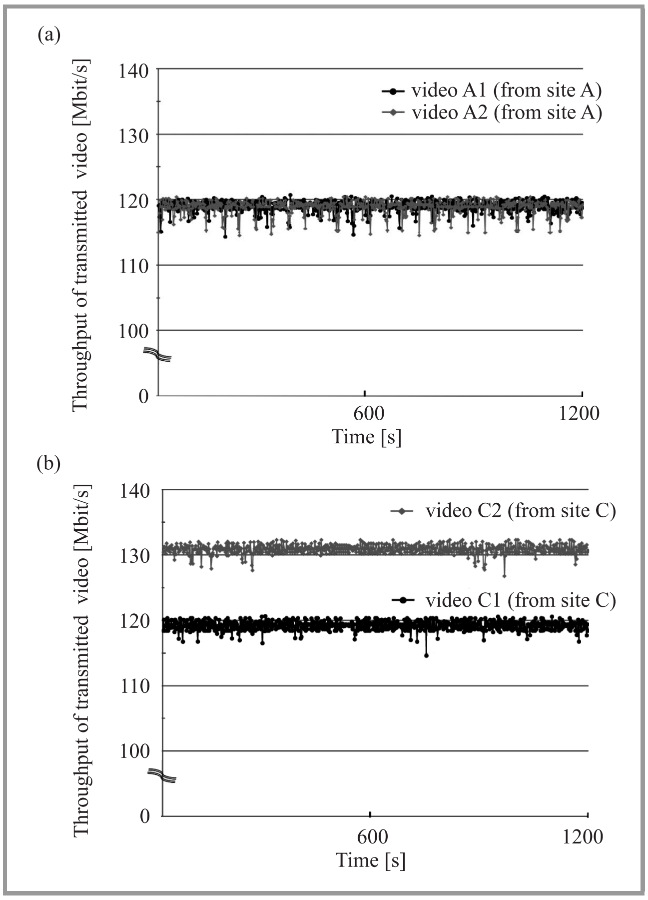


Fig. 8. Network throughput of each transmitted video: (a) A1 and A2; (b) C1 and C2.

been displayed more high-quality than magnified view of video image by a single small camera. As future works, we will try to display more high-quality video streaming of remote place over a wide range on tiled display wall in remote sites by increasing number of captured camera. In addition, we have not implemented the compositing for the boundary parts of each video by automatic processing, and have depended on the detail manual setting of each camera in this environment. We will need to study the technique which can composite the boundary parts of each image by the automated processing that doesn't depend on the position of the camera in the future works.

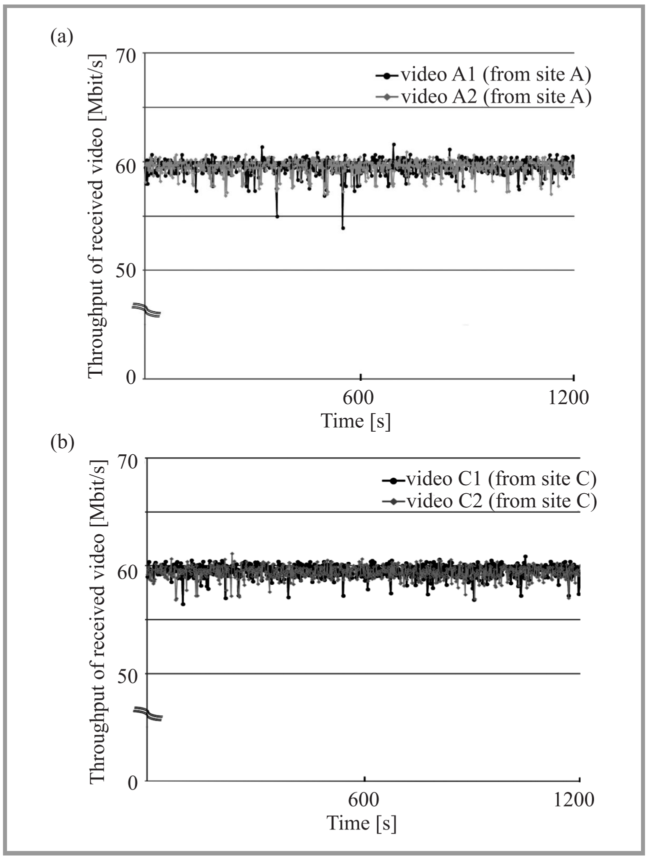


Fig. 9. Network throughput of each received video in tiled display wall *B*: (a) A1 and A2; (b) C1 and C2.

Then, we have measured the network throughput performance for each transmitted and received video streaming in this environment. The network throughput of transmitted video streaming from site A and C, and received video in site B is measured in this experiment. The measured results are shown in Figs. 8 and 9. The network bandwidth of transmitted and received video streaming about for 20 min are plotted the average value for measurement results of every 2 s. From measurement results, transmitted video streaming from each site have been observed about 120 Mbit/s. These results are considered that double network throughput has been generated to transmit same video streaming to tiled display walls in 2 sites. In addition, the steady throughput performance of 60 Mbit/s on average has been gained at the case of each received video streaming, and the values is considered a full performance of a camera.

4. Conclusion

In this paper, we have constructed remote communication environment with tiled display wall in multipoint sites and have conducted experiment in order to study the possibility of realizing realistic remote communication with multi-video streaming. From these results, these video streaming from each site have been shown to display more high-quality than expanded video image by single small camera. Moreover, we have measured the network throughput performance for each transmitted and received video streaming in this environment. From measurement results, the steady throughput performance has been gained at the case of each transmitted and received video streaming.

In remote communication between multipoint sites with video-conference system, the issue by sense of discomfort in communication to remote participants which wants to speak is caused. As a result, it becomes the factor of producing the misunderstanding is caused among participants in remote places. We will examine the possibility of high-presence remote communication to realize eye-to-eye contact with each other by using tiled display wall between multipoint sites. In addition, we will study that the possibility of new technique for automatic switching of transmission video in remote communication by the estimation of face direction from participant's video to realize effective remote communication between some participants distributed in multipoint remote sites.

References

[1] G. Kong, J. Stanton, S. Newhouse, and J. Darlington, "Collaborative visualization over the Access Grid using the ICENI Grid Middleware", in *Proc. UK e-Science All Hands Meeting*, Nottingham, UK, 2003, pp. 393–396.

[2] Y. Ebara, N. Kukimoto, J. Leigh, and K. Koyamada, "Tele-immersive collaboration using high-resolution video in tiled displays environment", in *Proc. IEEE 21st Int. Conf. Adv. Inform. Netw. Appl. AINA 2007*, Niagara Falls, Canada, 2007, vol. 2, pp. 953–958.

[3] J. Leigh, T. A. DeFanti, A. E. Johnson, M. D. Brown, and D. J. Sandin, "Global tele-immersion: better than being there", in *Proc. 7th Int. Conf. Artif. Real. Tele-Existence*, Esbjerg, Denmark, 1997, pp. 10–17.

[4] A. Sadagic, H. Towles, L. Holden, K. Daniilidis, and B. Zeleznik, "Tele-immersion Portal: towards an ultimate synthesis of computer graphics and computer vision systems", in *Proc. 4th Ann. Int. Worksh. Presence*, Philadelphia, Pensylvania, USA, 2001.

[5] K. S. Park, A. Kapoor, C. Scharver, J. Leigh, "Exploiting multiple perspectives in tele-immersion", in *Proc. Immersive Projection Technol. Worksh. IPT 2000*, Ames, Iowa, USA, 2000.

[6] N. Kelshikar, X. Zabulis, J. Mulligan, K. Daniilidis, V. Sawant, S. Sinha, T. Sparks, S. Larsen, H. Towles, K. Mayer-Patel, H. Fuchs, J. Urbanic, K. Benninger, R. Reddy, and G. Huntoon, "Real-time terascale impementation of tele-immersion", in *Proc. Int. Conf. Comput. Sci.*, Saint Petersburg, Russia, 2003.

[7] H. Towles, S. Kum, T. Sparks, S. Sinha, S. Larsen, and N. Beddes, "Transport and rendering challenges of multi-stream 3D tele-immersion data", in *Proc. NSF Lake Tahoe Worksh. Collabor. Virtual Real. Visual. CVRV 2003*, Tahoe City, CA, USA, 2003.

[8] S. J. Gibbs, C. Arapis, and C. J. Breiteneder, "TELEPORT-towards immersive copresence", *Multimedia Systems*, no. 7, pp. 214–221, Springer, 1999.

[9] W. Chen, H. Towles, L. Nyland, G. Welch, and H. Fuchs, "Toward a compelling sensation of telepresence: demonstrating a portal to a distant (static) office", in *Proc. IEEE Visualization 2000*, Salt Lake City, Utah, USA, 2000, pp. 327–333.

[10] P. Kauff and O. Schreer, "An immersive 3D video-conferencing system using shard virtual team user environments", in *Proc. 4th Int. Conf. Collab. Virtual Environ. CVE'02)*, Bonn, Germany, 2002, pp. 105–112.

[11] W. Matusik and H. Pfister, "3D TV: a scalable system for real-time acquisition, transmission, and autostereoscopic display of dynamic scenes", *ACM Trans. Graphics*, vol. 23, no. 3, pp. 814–824, 2004.

[12] C. Cruz-Neira, D. J. Sandin, and T. A. DeFanti, "Surround-screen projection-based virtual reality: the design and implementation of the CAVE", in *Proc. 20st Ann. Conf. Comp. Graphics Interact. Techniq. SIGGRAPH 1993*, Anaheim, California, USA, 1993, pp. 135–142.

[13] J. Leigh, T. A. DeFanti, A. E. Johnson, M. D. Brown, and D. J. Sandin, "Global Tele-Immersion: Better than Being There", in *Proc. Int. Conf. Artif. Real. Tele-existence ICAT'97*, Tokyo, Japan, 1997, pp. 10–17.

[14] T. Ogi and M. Sakai, "Communication in the networked immersive environment", in *Proc. ASIAGRAPH 2006*, Yokohama, Japan, 2006, pp. 67–72.

[15] T. Ando, K. Mashitani, M. Higashino, H. Kanayama, H. Murata, Y. Funazou, N. Sakamoto, H. Hazama, Y. Ebara, and K. Koyamada, "Multiview image integration system for glassless 3D display", *SPIE*, vol. 5664, pp. 158–166, 2005.

[16] Y. Ebara, Te. Nabuchi, N. Sakamoto, and K. Koyamada, "Study on eye-to-eye contact by multi-viewpoint videos merging system for tele-immersive environment", in *Proc. IEEE Int. Worksh. Netw.-based Virt. Real. Tele-existence INVITE 2006*, 2006, pp. 647–651.

[17] C. Li, H. Lin, and J. Shi, "A survey of multi-projector tiled display wall construction", in *Proc. 3rd Int. Conf. Image Graphics ICIG'04*, Hong Kong, China, 2004, pp. 452–455.

[18] T. Ni, G. S. Schmidt, O. G. Staadt, M. A. Livingston, R. Ball, and R. May, "A survey of large high-resolution display technologies, techniques, and applications" in *Proc. IEEE Conf. Virtual Reality VR 2006*, Alexandria, Virginia, USA, 2006, pp. 223–236.

[19] G. Humphreys, I. Buck, M. Eldridge, and P. Hanrahan, "Distributed Rendering for Scalable Displays", in *Proc. IEEE Supercomputing Conf. SC 2000*, 2000, Dallas, Texas, USA.

[20] G. Humphreys, M. Houston, Y. Ng, R. Frank, S. Ahern, P. Kirchner, and J. T. Klosowski, "Chromium: a stream-processing framework for interactive rendering on clusters", in *Proc. 29th Ann. Conf. Comp. Graphics Interactive Techn. SIGGRAPH'02*, San Antonio, Texas, USA, 2002, pp. 693–702.

[21] K. Doerr and F. Kuester, "CGLX: a scalable, high-performance visualization framework for networked display environments", *IEEE Trans. Visualization and Comp. Graphics*, vol. 17, no. 3, pp. 320–332, 2011.

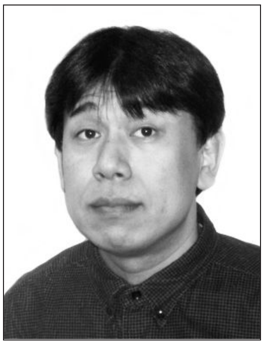
[22] L. Renambot, A. Rao, R. Singh, B. Jeong, N. Krishnaprasad, V. Vishwanath, V. Chandrasekhar, N. Schwarz, A. Spale, C. Zhang, G. Goldman, J. Leigh, and A. Johnson, "SAGE: the scalable adaptive graphics environment", in *Proc. Worksh. Adv. Collaborative Envir. WACE 2004*, Nice, France, 2004.

[23] J. Byungil, L. Renambot, R. Jagodic, R. Singh, J. Aguilera, A. Johnson, and J. Leigh, "High-performance dynamic graphics streaming for scalable adaptive graphics environment", in *Proc. Supercompuing SC 2006*, Tampa, Florida, USA, 2006, p. 24.

[24] Y. Ebara and Y. Shibata, "Study on tele-immersive communication with multi-video streaming on tiled display wall", in *Proc. IEEE 13th Int. Conf. Netw.-Based Inform. Sys. NBiS 2010*, Takayama, Gifu, Japan, 2010, pp. 439–444.

[25] Y. Ebara, N. Kukimoto, and K. Koyamada, "Evaluation experiment on eye-to-eye contact in remote communication with tiled displays environments", in *Proc. IEEE 22nd Int. Conf. Adv. Information Netwo. Appli. -Workshop- AINA 2008*, Okinawa, Japan, 2008, pp. 1017–1022.

[26] "SAGE: Scalable Adaptive Graphics Environment" [Online]. Available: http://www.sagecommons.org/



Yasuo Ebara received his M.Sc. and Ph.D. degrees in the Graduate School of Information Science, Tohoku University, Sendai, Japan, in 1997 and 2000, respectively. Since 2000 he has been with Kyoto University, Japan, where he was an Assistant Professor. Since 2008 he is Associate Professor at Osaka University, Japan. His research topic focuses on tele-immersion technique, network collaboration, and application of information system.
E-mail: eba@cmc.osaka-u.ac.jp
Central Office for Information Infrastructure
Osaka University
Ibaraki, Osaka, 567-0047, Japan