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Three-dimensional Flow Visualization in the Shared Immersive Virtual Space

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ABSTRACT : In order to overcome conventional difficulties for three-dimensional flow visualization, we have newly developed a shared immersive visualization system. This system is composed of two main technologies, a stereo flow visualization technology and a communication technology in an immersive virtual space, and we manage to observe and experience virtual flow fields by means of this system. In this study, we acutually visualized three-dimensional unsteady compressible flow using a volume rendering method, and carried out a remote presentation experiment through high speed network system. As a result, we could share visual information of three-dimensional flow structures and discuss those results between two distant places.

1. Introduction

Three-dimensional flow visualization is recently becoming more and more significant in the field of CFD. This is due to the fact that a large-scale numerical simulation widely spreads by a rapid advance of computer performance and it provides various flow structures as calculation results. In fact, we have already managed to calculate various three-dimensional flows even in a condition of several ten millions of grid points, and to succeed in visualizing those results and making a movie of them. While such a technology of numerical simulation provides numerous informations for us, three-dimensional flow structures that we have to analyze are becoming more and more complicated. In general, in order to visualize such flow fields, we adopt some three-dimensional visualization methods, contour surfaces, stream lines, particle path and volume rendering etc. However, these visualization methods are realized only through two-dimensional display of PC, and it is quite difficult for us to catch three-dimensional images. In this study, in order to overcome this problem, we utilized stereo visualization technology of flow field in an immersive virtual space. Especially, we introduced semitransparent iso-surface layers method (Kuzuu K, 2001) instead of a conventional volume rendering method so that we

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could interactively operate three-dimensional volume image in this system. On the other hand, when we actually try to visualize three-dimensional flow using this system, we always have to observe images in an immersive virtual space. This means that in case each observer is at different places, they cannot share those visualization images. As a result, we cannot discuss flow phenomena between two distant places. To resolve this problem, we combined above-mentioned system with some communication technologies (Ogi T, Yamada T, Kano M, Hirose M, 2001, Ogi T, Yamamoto K, Yamada T, Hirose M, 2001) for visual data.

2. Stereo visualization technology in an immersive virtual space

2-1 Immersive virtual display facilities

First, in consideration of a remote presentation experiment between two distant places, we utilized two immersive virtual display facilities. One is CABIN (Computer Augmented Booth for Image Navigation) at IML (Intelligent Modeling Laboratory), and the other is COSMOS (COsmic Scale Multimedia Of Six screens) at Gifu MVL (Multimedia Virtual Laboratory) Research Center. Both facilities are assemblies of large rear-projection screens. Those screens are arranged in a cube-like manner on three or four walls, the floor and the ceiling, each providing the user with a high-resolution, full-color computer generated image. On the other hand, stereo perception is achieved by means of stereo shutter glasses. Furthermore, a user's view is tracked with an electromagnetic sensor, and a stereo image is simultaneously adjusted with a user's motion. As a result, a highly immersive experience or a virtual reality image is provided for us. Figure 1 shows a configuration of this system.

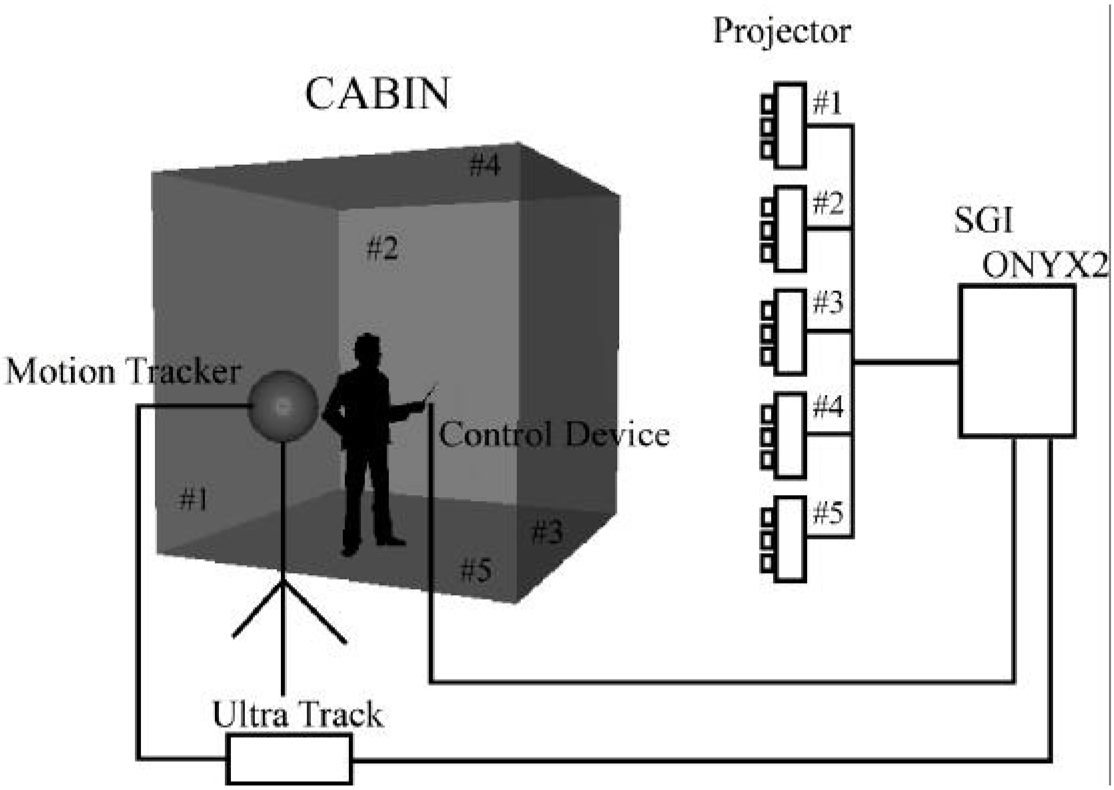

Fig.1 System Configuration of CABIN

2-2 Volume rendering in a virtual space

When we utilize above-mentioned immersive stereo visualization system, it is significant that we can experience three-dimensional volume visualization. From this point of view, volume rendering is the most effective method which we should adopt as a flow visualization. However, in the conventional volume rendering method, three-dimensional information of flow field is projected in two-dimensional screen after a physical value is spatially integrated in the eye-view direction. When we try to reproduce an image of volume rendering in the facility (CABIN or COSMOS), we need direct calculation of spatial integration during every operation. Time wasted for this process cannot be ignored and is too much for an interactive operation in an immersive virtual space. In order to overcome this problem, we introduced semitransparent iso-surface layers method for three-dimensional visualization (Kuzuu K, 2001). In this method, each iso-surface layer is composed of polygons whose vertices are defined in the three-dimensional space and three-dimensional images rapidly can follow changes of an eye-view. Therefore, this method seems to be quite suitable for operation in CABIN and COSMOS. By means of this technique, we can achieve the same effect as that of volume rendering. Figure 2 shows a sample of three-dimensional flow visualization using semitransparent iso-surface layers method.

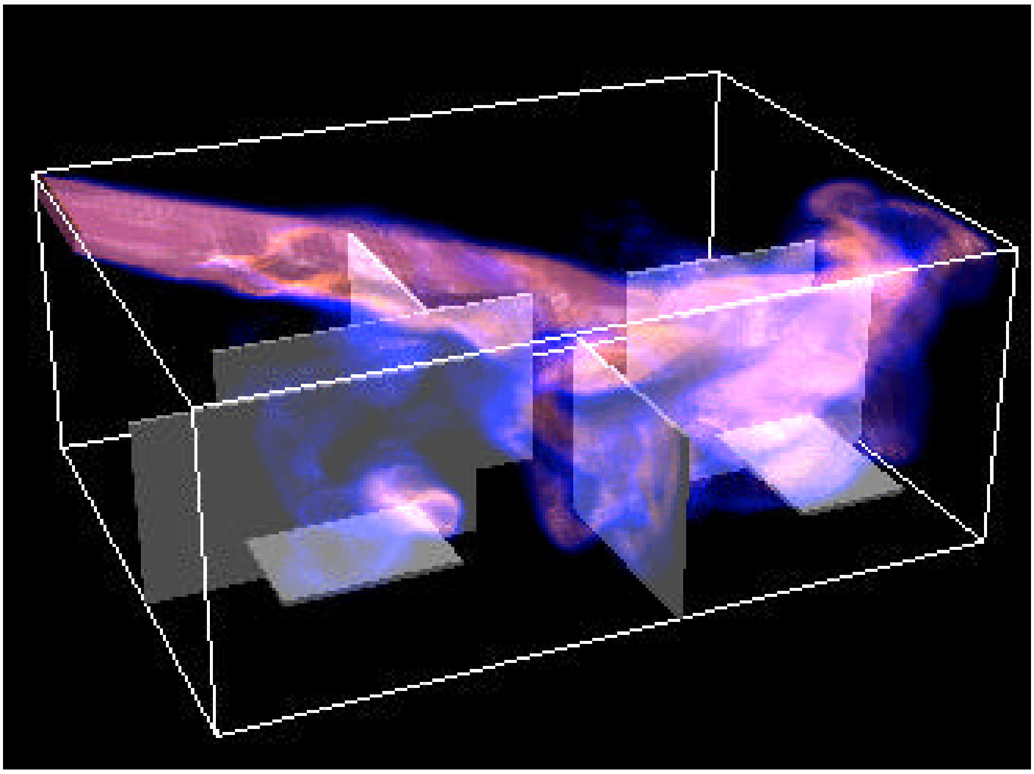

Fig.2 Flow Visualization by iso-surface layers
(Temperature distribution in the room)

3. Communication technologies for virtual images

In addition to above-mentioned visualization technology, a technology for communication is also introduced in this study. This system was developed so that we could simultaneously discuss about numerical or experimental results at two distant places. The system is composed of three functional technologies, CCBASE (Cyber Communication data Base), immersive telecommunication using stereo video avatar (Ogi T, Yamada T, Kano M, Hirose M, 2001) and cellular phone interface (Ogi T, Yamamoto K, Yamada T, Hirose M, 2001). CCBASE is a kind of database interface on network, and by means of this interface, users at two distant places can simultaneously share both database and operation for an application. In this system, a computer at each site plays a role of a server and a client, and an operation command on the server is simultaneously sent to the client. In this study, CABIN becomes a server and COSMOS a client. The second technology, a video avatar is a computer-synthesized three-dimensional image created using live video, and we can realize high presence communication between distant places. The last technology is an i-mode interface of cellular phone. Through this interface, even a user at a distant place can directly send a command to a server computer by wireless. The image of remote presentation using above-mentioned technologies is shown in Fig.3.

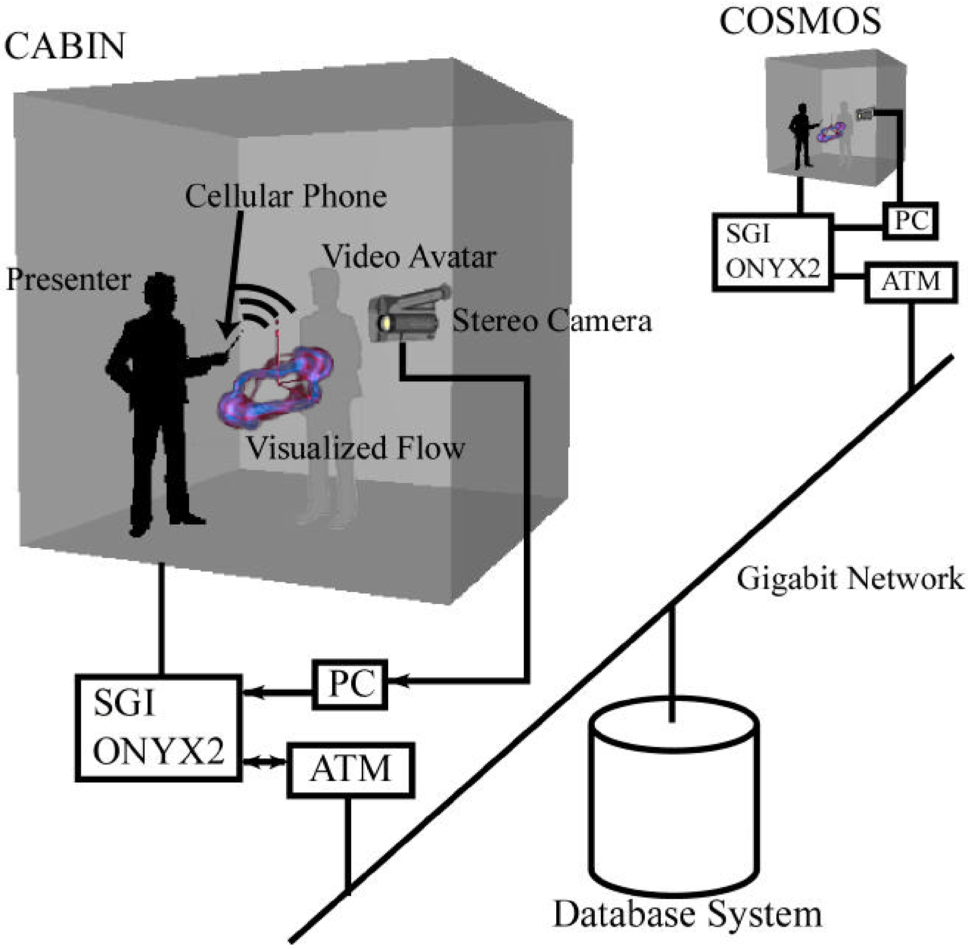

Fig.3 System Configuration for Remote Presentation

4. Remote presentation experiment

Using above-mentioned immersive stereo visualization and network system, we carried out a remote presentation experiment. In this experiment, CABIN at the University of Tokyo and COSMOS at the Gifu Techno-Plaza are connected through Gigabit Network System, and researchers at each site simultaneously observed the same visualization image. This image data is based on numerical analysis of supersonic opposing jet flow and its visualization by a semitransparent iso-surface layers method. The operation of this presentation was carried out at Tokyo site. As a result, researchers did not feel distance between two sites, and real-time discusssion about simulation results was quite satisfactory. The state of this experiment is shown in Fig.4

Fig.4 Operation of flow visualization in the shared immersive virtual space

5. Conclusion

In this study, we could build an environment where users at distant places could share three-dimensional flow image by combining an immersive stereo visualization system with network communication technologies. In fact, through a remote presentation experiment, we confirmed that the performance of this system was satisfactory and we could discuss simulation results in an immersive virtual space as if they are in one laboratory.

List of Movies

Movie 1: Temperature distribution in the room using iso-surface layers (1.77Mo)

Movie 2: Operation of flow visualization in the shared immersive virtual space (1.12Mo)

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