# VizGrid: Virtualized Collaboration Environment with 3D Images

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**In this paper, we describe a remote collaboration environment based on Volume Communication technology that handles 3D images as objects shared among participants. Three-dimensional images are intuitive and familiar. In addition we can often use them to express ideas in a more natural way than with words. In VizGrid, which is a national joint-project between universities and Fujitsu, we are developing a communication technology for handling 3D images and a remote collaboration system. This technology generates, compresses, transmits, displays, and searches for 3D images. The collaboration system based on Volume Communication enables eye-to-eye contact and represents relative positions between participants and shared objects. Also, when people carry out tasks they have been assigned by others in their group, our system offers facilities for maintaining links between co-workers who access the same documents and visualizing their relationships in 3D. In the last part of this paper, we propose a way to represent a real-time collaboration space as a part of asynchronous space. This environment helps co-workers to conduct frequent conversations with each other by presenting interrelationships while switching between two types of workspace.**

## 1. Introduction

Collaboration environments for joint research between different research fields and different countries have become more important recently because the boarders between fields are becoming increasingly fuzzy. In particular, the most advanced research often needs special research facilities and devices; consequently researchers have to collaborate with remote researchers to control such facilities from remote laboratories. In these situations, they can receive slightly different impressions according to their background, which can lead to misunderstandings.

Three-dimensional images are intuitive and easy for humans to understand, so collaboration environments that support 3D images are expected to make it easy for remotely located researchers to share information. Conventional 2D images show images from the viewpoint of the observer, but 3D images can be viewed from any viewpoint. Devices and infrastructures for viewing and processing 3D images have recently become available. For example, displays that show 3D images without the need for special glasses have become familiar. We can expect that grid computing[1] will supply the resources and fast 3D processing required for smooth human interactions. The recent advance of broadband networks to the 10 Gb/s-plus region has made it practical to transmit the huge amounts of data required to represent 3D objects.

The purpose of VizGrid,[2),3)] which is a joint-research project between universities and Fujitsu funded by the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT), is to develop a remote collaboration environment in which researchers of different backgrounds can share 3D images. In particular, VizGrid will be useful in medical science and nuclear fusion experiments. In medical science, for example, collaboration environments with 3D images are supporting smooth joint-research between doctors and computational scientists in remotely located sites (**Figure 1**). In this research, a CT (Computerized Tomography)/MRI (Magnetic Resonance Imaging) image is obtained and then 3D data is generated. Next, a vessel wall is extracted from the 3D data through collaboration. Then, computational scientists simulate the blood flow in a diseased artery using high-performance computers. Lastly, they collaborate and discuss how and why the disease occurred and discuss effective medical treatments while looking at 3D simulations of the blood flow.

In this paper, we introduce and describe the effectiveness of a collaboration environment with 3D images that Fujitsu is developing in this project. In Section 2, we look at current collaboration systems and their problems and describe a communication technology we have developed for sharing 3D images called Volume Communication. In Section 3, we describe a 3D collaboration environment that uses Volume Communication and its effectiveness. We conclude this paper in Section 4.

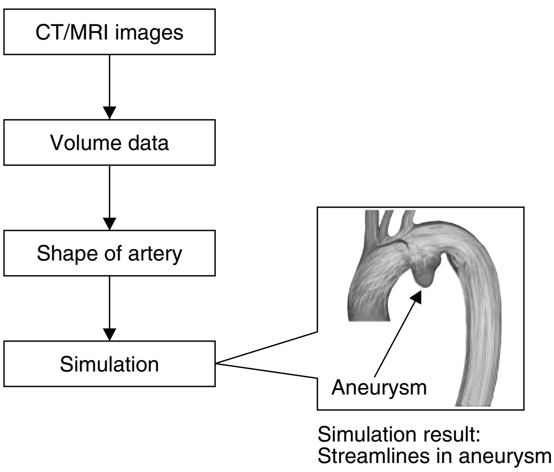


Figure 1
Example of use in medical science.

## 2. Collaboration environments with 3D images

### 2.1 Overview of collaboration environments

We can identify two types of collaborations in both remote and face-to-face situations. In one type, members collaborate and exchange information in real time, for example, as in a conventional meeting. In the other type, called asynchronous collaboration, members complete tasks they were assigned in previous real-time collaborations. Practical collaborations repeatedly switch between these two types.

It is well known that collaborations between people in the same office are more effective than remote collaborations. In face-to-face situations, real-time and asynchronous collaborations are not clearly distinguishable. When people working in the same office perform their tasks, they frequently make brief, unscheduled collaborations. According to an investigation of the working styles of white-collar workers in the U.S.,[4] about half of all collaborations are unscheduled. This report concluded that the rate of unscheduled collaborations between workers in different offices is inversely and geometrically proportional to the distance between their offices. Workers who are physically close to each other can easily keep track of the status and activities of co-workers. Usually, the small events that lead to small collaborations do not seriously disturb ongoing work, because such collaborations are necessary to complete the work. This suggests that remote collaboration systems must enable easy switching between real-time and asynchronous collaboration.

### 2.2 Two collaboration environments

Video conferencing systems are most widely used now in real-time collaborations. However, they only have functions for transmitting audio-visual data captured by microphones and video cameras. They lack two important functions for supporting collaboration among people: a function for creating remote views of a scene and a function for ensuring that objects appear the same in each space in the environment (**Figure 2**). Also, today's systems cannot adequately represent interactions between personal spaces and shared spaces.

During conversations, people instinctively communicate with each other using eye gestures. For instance, enthusiasm can be conveyed by wide-open gazes into other peoples' eyes and people experiencing a lack of confidence often look down. To show an object that a participant is looking at, there must be a camera right in front of the participant; however, this is where the display is positioned. One solution is to place a half-mirror over the display so the camera can be positioned elsewhere. Another way is to generate front-facing views of participants using computer graphics technology.[5] In addition, people tend to look at the next speaker when they stop talking[6] and this behavior facilitates natural transitions between speakers in a conversation. Hydra[7] and MAJIC[8] support this with multiple cameras for each participant, each of which shows who each participant is looking at.

Next, we explain that combining participants' images with shared documents helps the participants understand the interactions between themselves visually. In particular, pointing to shared objects can not only clarify the point of a current discussion but also encourage the exchange of opinions.[9] Also, displaying close-ups of participants hands over shared documents can often help the participants convey useful information.[10),11)] Many experimental systems have shown the importance of direct attention with eyes; however, several restrictions remain in practical systems. Recent research of computer vision and computer graphics with 3D graphics is helping us overcome these restrictions. Tele-immersion[12] is currently one of the most important research topics.

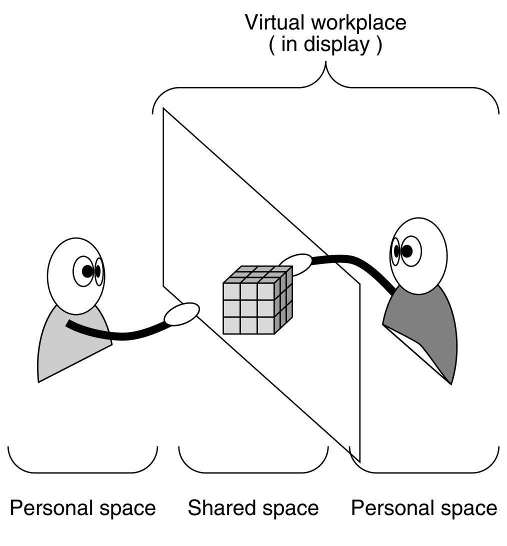


Figure 2
Real-time collaboration environment.

Next, we consider the representation of participants' current status in asynchronous collaborations. E-mail and document sharing systems are widely used in remote collaborations. Also, people performing related, concurrent tasks are beginning to use instant messaging and presence services so they can keep up to date with their colleagues' progress.[13,14] These systems overcome some of the problems with asynchronous collaboration, because they help workers make brief collaborations so they can complete their tasks.

Current systems are too simple to support collaboration, because they only indicate the simple status of co-workers, for example, whether they are online. A system for collaboration would need to, for example, show the status of a document so co-workers can easily see the modifications that have been made to it. Also, it would need to show the status of remote co-workers in more detail, so co-workers can better decide how to proceed with their work.

## 2.3 Volume Communication

We have described the need for 3D images in collaboration environments. Next, we introduce the infrastructure for communication of 3D images.

There are two kinds of data for representing 3D images: surface data and volume data. In VizGrid, 3D images are constructed from 3D arrays of voxels as shown in **Figure 3 (a)**. Voxel values can indicate color, brightness, a vector value, or any other parameter. Volume data not only gives information about an object's outward appearance, but can also give information about the object's interior. In addition, volume data gives superior image quality and performance than surface graphics when multiple 3D images are processed together.[15] The amount of 3D data required for surface graphics is small, but the procedure for combining certain images becomes complicated. Also, surface graphics cannot be used to represent a 3D collaboration space. Virtualized collaboration spaces can be composed of 3D images of participants and 3D objects that are shared between participants {**Figure 3 (b)**}. The Volume Communications suites consist of several stages for transmitting volumetric data. The stages are: generation, compression, transmission, decompression, display, archiving, and searching (**Figure 4**). When an application for remote collaboration uses this middleware, it must handle multiple streams of transmission data simultaneously. In addition, if there is too much volumetric data to transmit to a remote site, the sender application can divide it into smaller sets, send each set via different paths to the receiver application, which then combines the sets and displays them. Therefore, the system functions as a node on a multi-stream network and consequently requires a synchronization function. The VizGrid project will also develop a function that searches for 3D images in archives using technology for finding 3D features. This environment for Volume Communication can establish a 3D collaboration environment at multiple remote sites. In addition, it can also retrieve 3D images that are archived during collaboration.

We are jointly developing a Volume Communication infrastructure with other members of this project.

## 3. Visualized collaboration system with 3D images

### 3.1 Workspace for real-time collaboration

In this section, we explain the required functions and advantages of a remote real-time collaboration environment that uses Volume Communication technology. Our aim is to represent an entirely virtualized workspace of participants and shared objects as volume data and display it from different viewpoints at multiple sites. This environment creates a virtual office that enables participants to make eye-to-eye contact with each other and visualize their relative physical positions in the office. Consequently, they can feel as if they were in the same office.

To represent an object as volume data, the system must first convert it from the form in which it was originally represented. There are various methods for generating volume data from the outputs of multiple, calibrated video cameras. We use a technology developed by the Matsuyama

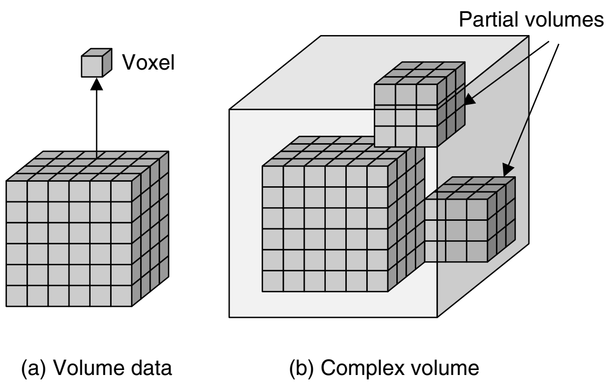


Figure 3
Format of volume data.

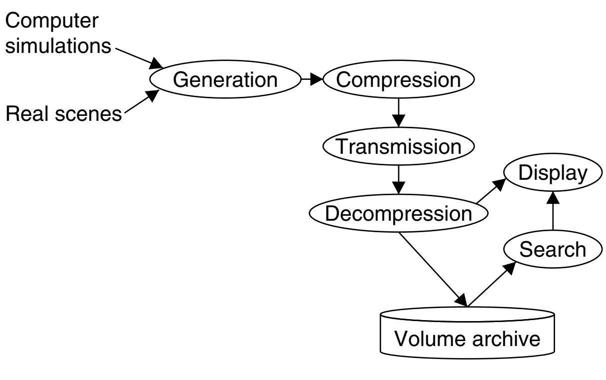


Figure 4
Volume Communication suite.

Lab. of Kyoto University.[16] **Figure 5** outlines our system. Multiple, calibrated video cameras take images of the objects of interest. Then, the system constructs volume data of the objects in real time using a PC cluster. In our prototype, five video cameras capture images of the participants' upper bodies and send them to the PCs over an IEEE 1394 interface, which then generate the volume data.

The natural, easy-to-understand way for a participant to indicate something about a shared object is to use hand gestures. For example, a position can be indicated with a finger, a surface region with a palm, and a direction with a finger or hand. To show hand gestures more precisely, the system needs to generate separate 3D data for the gestures, because they will need to be displayed at a higher resolution and frame rate than the participants. The system will also have to combine the partial volumes of participants, objects, and hands and then display the completed scene from different viewpoints to each participant.

Another condition for realizing immersive environments is shorter transmission delays between sites. If this delay becomes too long, people cannot converse naturally and do not feel they are in an immersive environment. Generally, delays longer than 250 milliseconds adversely affect conversation. Although current networks cannot provide sufficient bandwidth and low latency for teleimmersion, these requirements will be met by future networks. Accordingly, the system has to give priority to important hand and arm movements, unless transmission delays seriously affect interactions. This mechanism overcomes some of the difficulties associated with remote collaboration, because part of the scene, for example, objects that participants are looking at and objects being pointed to, will be transmitted and displayed first.

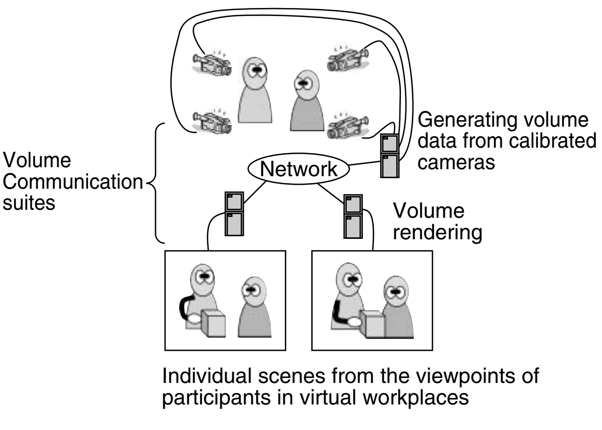


Figure 5
Collaboration system with 3D images.

## 3.2 Workspace for asynchronous collaboration

To perform their tasks, project members usually require various kinds of interactions, because many of their tasks are closely interrelated. For effective collaboration, it is important that the members finish their own tasks on time; otherwise, the entire project could be delayed. If necessary, a member can briefly interrupt another member to get some ideas and common information, for example, deadlines. If members are in the same office, they can easily see if somebody is free to talk, and this kind of information is easily transmitted to other members in the office. However, in a remote collaboration, people may waste time waiting for others to become available. To support a joint research, if people already know each other, they can often transmit their presence and activities naturally to effectively collaborate as if they were in the same office. An office provides clues that make it easier to contact other people in the office, and such contacts provide new information about other people. These are the advantages of this type of collaboration environment.

We have developed a document sharing system for researchers called VizSquare (**Figure 6**). This system assumes that the workflow has been roughly defined; for example, as is the case in an ordering system designed to avoid mistakes and wasted time due to incorrect operation. However, in a complex human collaboration, particularly for researchers, the workflow may not be strictly defined, and although the collaboration's members understand the workflow, it may be difficult for non-members to understand. The main feature of this system is that it makes it possible to determine the work status by examining the status of shared documents. VizSquare automatically generates the meta-information required to organize reference documents from document contexts and structures. Users of this system can analyze information by reorganizing documents according to attributes such as Themes, Timeline, and Authors. This helps the users because different organizational views can provide new clues about relationships between documents.

In the next step, we plan to present the status of participants and shared documents and the relationships between them by analyzing the access records for the creation, modification, and referencing of shared documents. Access records show the relationships between participants and information. Also, common readership of documents shows the relationships between participants (**Figure 7**). For example, an enhanced system may show the relevant people a document created by person A and then send it to other people that have previously referenced it. In this relationship, people are performing different tasks at the same time. In this case, each task has related documents and co-workers. Tasks that are closely related are in the foreground of the 3D space, and the other tasks are in the background. Therefore, users performing the same tasks at the same time see them in the foreground, which stimulates conversation about them. Because of the usefulness of this part of the virtualized workspace, it can be easily switched to a real-time collaboration environment (Figure 2).

Regarding the participants' views, although all scenes in real-time collaboration are generated by volume rendering, not all of the scenes in an asynchronous collaboration are generated by volume rendering. We apply volume rendering in asynchronous collaborations because the system makes it easy to switch between the real-time workspace and asynchronous workspace. We think that realism is not so important in the asynchronous workspace, because users require only basic information about the status in the collaboration space and detailed information can unnecessarily distract participants away from their current tasks.

## 4. Conclusion

In this paper, we described a remote collaboration environment with 3D images. Our system supports two types of collaboration: real-time collaboration, as occurs for example, in a meeting, and asynchronous collaboration, in which people carry out individual tasks assigned by co-workers. The real-time workspace is represented

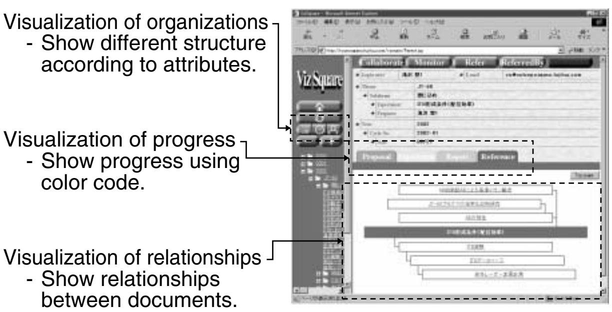


Figure 6
VizSquare – a research information portal.

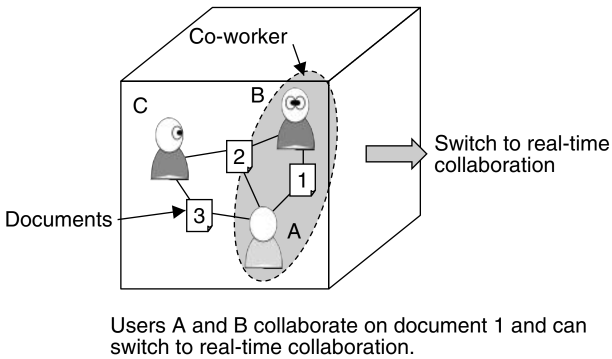


Figure 7
Asynchronous workplace.

as a part of the asynchronous workspace in 3D collaboration space.

Three-dimensional images assist in these collaborations because they are intuitive and familiar to people. Researchers in different fields can often communicate with 3D images more easily than with words. In asynchronous collaboration, visualized relationships between co-workers and documents help co-workers grasp the status of each other's individual task.

We expect that our system will promote frequent and brief remote collaborations.

The collaboration environment based on Volume Communication can represent various interactions that occur in a collaborative workspace. In real-time collaboration, participants and shared objects are represented as partial volumes and their interrelations represent the interactions between them, for example, interactions indicating who or what a participant is looking at or pointing to. In asynchronous collaboration, co-workers and documents represented as partial volumes also express participants' actions, for example, creation, modification, and accessing a document.

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