A Virtual Workspace for the Collaborative Design

Makoto Sato and Masahiro Ishii
Precision and Intelligence Laboratory,
Tokyo Institute of Technology

4259 Nagatsuda, Midori, Yokohama, 227 Japan
+81.45.924.5050, +81.45.921-0898(fax)
email:msato,mishii@pi.titech.ac.jp

Abstract

This research aims at the realization of a virtual workspace for the collaborative design of 3D objects. Based on an analysis of an ordinary collaborative design, we illustrate that a collaborative workspace consists of *a dialog space* and *an object space*. In the dialog space, a participant interacts with partners, and in the object space with an object. The participants enter the dialog space and the object space in turn, appropriately. In addition, collaborative design of 3D objects is carried out with *multi-modal* interactions; visual, auditory, and haptic. Namely, a virtual workspace for the collaborative design of 3D objects must support these interactions without contradiction in either time or space. We propose a shared virtual workspace for a pair of participants. In order to implement the workspace, we take into account the following:

- the necessity of multi-modal interactions,
- the need for participants to switch between the dialog space and the object space quickly and appropriately.

1 Introduction

We believe that design is a social activity; the interactions of individuals within groups and the relation of groups to one another. The communication needs of designers are increasing as their projects become more complex and design teams become distributed; the communications solutions available to designers may have a profound effect on the way design is practiced. This research aims at the realization of a shared virtual workspace for the design of 3D objects. It requires both support of human-to-human communication and manipulation of virtual objects; *interactions among participants* and *interactions between a participant and an object.*

Tele-presence is a way of giving distributed participants a feeling that they are in the same conference room. The goal is to transmit *information* that occurs between participants; body language, hand gestures, eye contact, meta-level communication cues, knowing who is speaking and who is listening, voice cues, focusing attention, etc. Tele-presence facilitates effective management and orchestration of remote meetings by the natural and practised techniques used in face-to-face meetings[1, 2, 3].

Many input devices for computers have been proposed; keyboards are used for symbolic information and mice for two dimensional information. The handling of 3D objects in a virtual environment requires an efficient input device which can handle these virtual objects as humans handle objects in the real world. Furthermore, the effect of input in the virtual environment must appeal to the sense organs because humans perceive the outside world from their senses in the real world [4]. Important perceptual information while handling 3D objects is obtained from vision, force (haptic) sensation, auditory sense, etc. While some visual and auditory displays are in practical stages, force displays are still in experimental stages. Although a number of force displays have been built [5, 6, 7, 8], they are unsuitable for the design of 3D objects. There has been no system that fulfills both of the following two requirements: (1) pick-and-place task can be done, and (2) sufficient DOFs(degree of freedom) and range of hand motion should be secured. The difficulty in the realization of a force display is to implement a mutual effect between the display and an operator, because haptic sensations must be generated mechanically. The DOFs and the size of the operatable space are important in the design a force display, and the realization of a force display that has many DOFs and a large space is difficult.

There have been several systems proposed to support face-to-face conversations and shared drawing activities [9, 10, 11, 12]. In addition, there are many reports on sharing computer generated 3D space. Codella implemented a demonstration system of a multi-person virtual world [13]. Zyda et al. have develpoed a large-scale networked 3D virtual environment and visual simulation systems [14]. Takemura & Kishino built a cooperative work environment by combining head tracking stereoscopic displays and DataGloves, and compared and explored the locational relation between a pair of participants on object layout tasks [15]. However, there has been no system that fulfills both of the following two requirements: (1) collaborative design of 3D object, and (2) face-to-face conversation.

In this work, we aim at the realization of a shared virtual workspace for the design of 3D object. In section 2, we first analyze the ordinary collaborative design by taking note of what interactions take place. Then, in section 3, we consider the realization of the indispensable interactions in a shared virtual workspace. Section 4 describes the implementation of the prototype system ergonomically. Experimental results on a simple collaboration with the system are presented in section 5. Finally, concluding remarks are given in section 6.

2 Interactions in Collaboration

In this section, we analyze the collaborative modeling, e.g. sculpting, as a collaborative design of 3D objects. To simplify the problem, let the participants be two people and assume that only one participant can modify the object at a time. The design process is as follows:

Discussion They put the object on a worktable. They discuss to get a consensus of opinion about a shape that they want to make.

Modification One of the participants, possibly with a tool, modifies the object to be similar to the consensus, and the other participant observes.

Presentation & Evaluation The former hands the object over to the latter to let him go into details. They confirm the modification.

They repeat these phases until they agree, as shown in Figure 1. During the process, there are

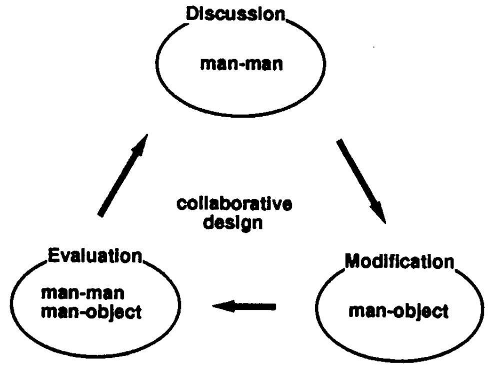

Fig.1 Collaborative design process

many interactions between the participants and between a participant and the object. Examples of the kinds of interactions which may occur during each phase are given below.

Discussion facial expression, gestures, eye contact, focusing attention, spoken language, voice cues, etc.

Modification observation on the object, weight, inertia, collisional force, reaction from the object, processing sound, collisional sound, teaching by force, etc.

Presentation & Evaluation facial expression, gestures, eye contact, focusing attention, spoken language, voice cues, teaching by force, observation on the object, weight, inertia, collisional force, reaction from the object, etc.

This analysis shows two points. First, collaborative workspace consists of *a dialog space* and *an object space*, as shown in Figure 2. In the dialog space, a participant interacts with partners, and in the object space, with an object. The participants enter the dialog space and the object space in turn, appropriately. Then, collaborative design of 3D objects is carried out with *multi-modal* interactions; visual, auditory, and haptic interactions.

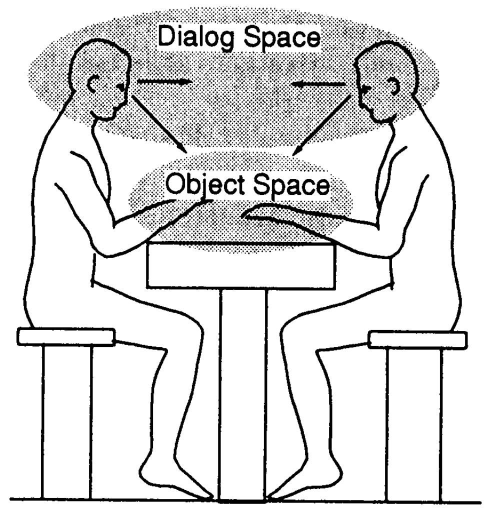

Fig.2 Dialog space and object space

3 Implementation of Interactions

In order to facilitate the collaborative design of 3D object between distributed participants, a shared virtual workspace must support the interactions described above, without contradiction in either time or space. This section describes how to implement the interactions.

3.1 Visual Interactions with Object

Object is the subject of the collaboration. It visually explains the content of the work through an image and is used to inform the participants about the work. Therefore, visual interactions with the object requires a human interface that can facilitate discovery of problems and inspiration for solutions. In the case of the design of 3D objects, real-time CG(computer graphics) is now useful.

3.2 Auditory Interactions with Object

An advantage of using auditory information is that a human operator can monitor the process in the background, whereas visual information requires direct attention. It is not difficult for a computer to synthesize auditory information, such as collisional sound, processing sound, etc.

3.3 Haptic Interactions with Object

In order to implement a 3D spatial interface device for the design of 3D objects, we identify the following four design requirements must be supported:
(1) direct manipulation using hands,
(2) force feedback,
(3) pick-and-place tasks[1],
(4) sufficient DOFs and range of motion.

We have proposed a 3D spatial interface device using strings, pulleys, and motors, called SPIDAR (SPace Interface Device for Artificial Reality), as shown in Figure 3 and Figure 4. The position of an operator's fingertip is measured by the lengths of the strings that are connected with a finger cap. The strings tensed by motors create force sensations. SPIDAR is very easy to use; the operator merely attaches the finger caps to his fingers. Unlike some other systems, there are no constrains imposed upon the movement of the operator's fingers other than those imposed by the model itself. We constructed a virtual environment for pick-and-place tasks with SPIDAR and 3D computer graphics. The operator could both see and feel the results of his hand motions in a very natural way[16].

3.4 Interactions with Partner

Although verbal communication is very important for the partners to indicate each other's intention, it leaves something to be desired. Giving distributed participants a feeling that they are in the same place is also important. It requires visual, auditory, and haptic interactions by means of spatial non-verbal interfaces. For instance, the line of sight can show what interests a partner, hand gestures can specify a notable point, and haptic information is useful for perception of manipulating the same object by many users.

Cameras and displays are useful for the visual interactions, microphones and audio speakers for auditory interactions, and SPIDAR, as described above, for haptic interactions. It is essential that these interactions can be carried out without contradiction in either time or space.

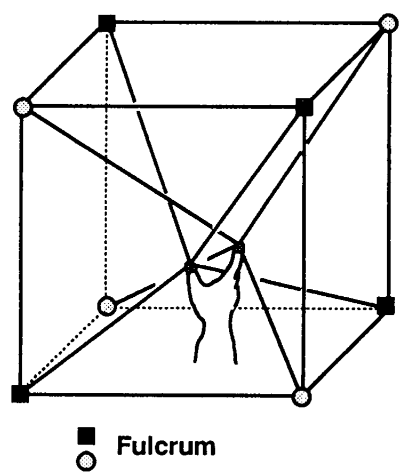

Fig.3 Overview of SPIDAR

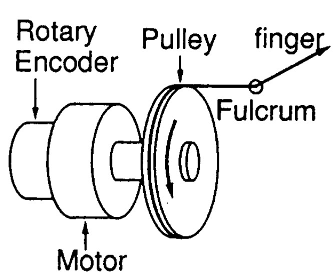

Fig.4 Motor and encoder at fulcrum

[1]A pick-and-place task consists of manipulating position and orientation of a 3D object.

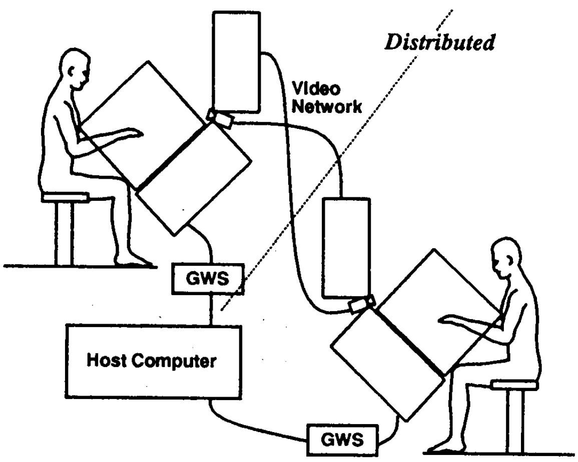

Fig.5 Networked System

4 System Configuration

In order to implement Networked SPIDAR, we identify the following design requirements.
(1) the multi-modal interactions can be used,
(2) the participants can switch between the dialog space and the object space quickly and appropriately.

Figure 5 shows the system configuration of Networked SPIDAR. The CG screen which displays the virtual workspace is set at a slant position. SPIDAR, which is for haptic interactions, is set in front of the screen. It is necessary to preserve spatial relation from site to site to give the illusion of a face-to-face meeting. Furthermore, switching between the dialog space and the object space must be done smoothly. Namely, the screen which displays the partner's facial image and the screen which displays the virtual workspace must be located close together to preserve the locational relation between the partners and between the partner and the object.

Data communication is carried out using a local area network, and visual/auditory communication using a video network. The system also includes microphones and audio speakers to support communication by voice.

5 System Evaluation

Figure 6 shows a pair of users facing each other and manipulating virtual blocks located between them. The sharing of the virtual workspace is very natural. When a participant moves a virtual block at his site, the CG image at the other's site is also refreshed simultaneously. Both of the participants may see the movement but only the former may feel the weight, stiffness, etc. When a block collides with another object, the collisional sounds are made at both sites. While the participants are in contact with a virtual object, they feel each other's force. The force increases the feeling of intimacy. Participants can easily see each other's faces when needed, by only raising their faces. This is because the facial image is located close above the shared virtual workspace. They also can discuss the arrangement of blocks by voice.

Fig.6 Networked SPIDAR

5.1 Experiment

More experimental data are necessary to perform a statistical analysis of user performance with Networked SPIDAR. The difficulty in the realization of holding a virtual environment in common stems from consistency, particularly when a virtual object is manipulated by many participants. Thus, we took up *the hand-over task* to investigate the efficiency of haptic interactions, and paid attention to the moment when both participants were in contact with a virtual object. The experimental task was to hand a virtual toy block to a partner. The subjects were four pair of adult males, one party givers and the other party takers. Each block was a five centimeter cube and fifty Grams in weight. The distance between both participants was supposed to be eighty centimeters. The experiment was conducted to estimate the effect of haptic information under two conditions: with and without haptic interactions between the participants.

In consequence, the subjects without the interactions occasionally failed in the task – the block fell to the virtual ground. Using only visual interactions, it was easy for the giver to misunderstand when the taker had grasped the object so that the giver might release it. In the case of using the interactions, the task was done easily and perfectly. The haptic interactions allowed the giver to know when the taker had successfully grasped the object, and consequently the giver never released prematurely. Figure 7 shows the average time while both participants were in contact with the block. The collaborative workspace supporting haptic interactions between the participants has much better performance than one which doesn't support them. In addition, the average time varied widely in the case without haptic interactions between the participants.

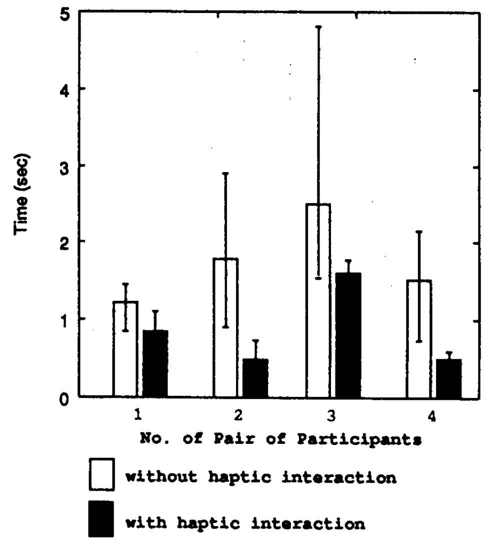

Fig.7 Effect of haptic interaction between participants

6 Conclusion

This research aims at the realization of a shared virtual workspace for the design of 3D objects. Based on an analysis of a collaborative modeling, we illustrated that a collaborative workspace consists of a dialog space and an object space. A participant of the collaboration interacts with a partner in the dialog space, and with the object in the object space. The participants enter the dialog space and the object space in turn, appropriately. We also found that the collaborative design of 3D objects is carried out with the following types of multi-modal interactions – visual, auditory, and haptic interactions. A shared virtual workspace must support these interactions without contradiction in either time or space. We have proposed a shared virtual workspace for a pair of participants. In order to implement the workspace, we took into account the following:

- the necessity of multi-modal interactions,

- the need for participants to switch between the dialog space and the object space quickly and appropriately,

The users collaborated on an object layout task in a very natural way with the prototype system. In addition, through the *hand-over* tasks performed with this system, we realized that the haptic information reflecting interaction between the participants contributes to efficiency of the work, and increases the feeling of intimacy between the participants. Furthermore, it is useful in managing the shared virtual environment consistently. This is because the haptic information enforces the consistency, i.e. it prevents the participants from moving a virtual object contradictorily. Further investigation is needed to estimate the auditory interactions with the objects. Future work will be aimed at multi-user collaboration and eye-contact.

References

[1] Hunter, G., "Teleconference in Virtual Space, " *Information Processing 80*, pp.1045-1048, North-Holland Pub., 1980.

[2] Buxton, B., and Moran, t., "EuroPARC's Integrated Interactive Intermedia Facility(IIIF): Early Experiences," *IFIP WG8.4 Multi-User Interfaces and Applications*, pp.11-34, Amsterdam, 1990.

[3] Fish, R. S., et al., "The VideoWindow System in Informal Communications," *CSCW '90*, Los Angels, pp.1-11, 1990.

[4] Sutherland, I., "The Ultimate Display," *IFIP Congress*, pp.506-508, 1965.

[5] Burdea, G., et al., "A portable dextrous master with force feedback," *Presence*, 1(1), pp.18-28, 1992.

[6] Brookes, F. P., et al., "Project GROPE - Haptic displays for scientific visualiation," *Computer Graphics*, 24(4), pp.177-185, 1990.

[7] Iwata, H., "Artificial reality with force feedback: Development of desktop virtual space with compact master manipulator," *Computer Graphics*, 24(4), pp.165-170, 1990.

[8] Minskey, M., et al., "Feeling and seeing: Issues in force display," *Computer Graphics*, 24(2), pp.235-244, 1990.

[9] Tang, J. C., and Minneman, S. L., "VideoDraw: A Video Interface for Collaborative Drawing," *CHI '90*, pp.313-320, Seattle, 1990.

[10] Minneman, S. L., and Bly, S. A., "Managing a Trois: A Study of a multi-user drawing tool in distributed design work," *CHI '91*, pp.217-224, New Orleans, 1991.

[11] Ishii, H., "TeamWorkStation: Towards a Seamless Shared Workspace," *CSCW '90*, pp.13-26, Los Angeles, 1990.

[12] Ishii, H., and Kobayashi, M., "ClearBoard: A Seamless Medium for Shared Drawing and conversation with Eye Contact," *CHI '92*, pp.525-532, Monterlay, 1992.

[13] Codella, C., "Interactive Simulation in a Multi-Person Virtual World," *CHI '92*, pp.329-224, Monterlay, 1992.

[14] Zyda, M., et al., "NPSNET: Constructing a 3D Virtual World," *1992 Symposium on Interactive 3D Graohics*, pp.147-156, Massachusetts, 1992.

[15] Takemura, H. and Kishino, F., "Cooperative Work Environment Using Virtual Workspace," *CSCW '92*, pp.226-232, Toronto, 1992.

[16] Sato, M. and Ishii, M., "A 3D Interface device with force feedback: A virtual work space for pick-and-place tasks," *Proc. of the IEEE VRAIS'93*, Seattle, pp.331-335, 1993.