Chapter 10

FreeWalk: SHARED VIRTUAL SPACE FOR CASUAL MEETINGS

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Abstract

In this chapter we present FreeWalk, a meeting environment for casual communication in a networked community, which provides a 3D common area where everyone can meet and talk freely. FreeWalk represents participants as 3D polygon pyramids, on which their live video is mapped. Voice volume remains proportional to the distance between sender and receiver. For evaluation, we compared communications in FreeWalk to a conventional desktop videoconferencing system and a face-to-face meeting.

1. INTRODUCTION

Most computer systems for collaborative work provide desktop videoconferencing tools for business meetings. However, meetings aren't always formal or business related. Casual meetings such as chatting during a coffee break or in a hallway occur daily. They maintain human relationships, and also play an important role in collaboration. We believe that conventional desktop videoconferencing systems, which multicast pictures and voices, can't support casual meetings.

We aim to support everyday activities by forming a community through computer networks. Our product FreeWalk[1, 2], a social environment for communication, lets people meet casually in shared three-dimensional (3D) virtual spaces such as a park or a lobby. The following list describes the inherent features of casual meetings and how FreeWalk can support them.

1. *Casual meetings*

   In conventional desktop videoconferencing systems such as Office Mermaid[3], participants turn on the system when they start a meeting. When in operation, the system displays the faces of all participants on their workstations, which hinders free conversation. The system lists the participants before the meeting starts, thereby prohibiting accidental encounters with other participants.

   Several desktop videoconferencing systems have tried to extend their functions to support casual meetings. Cruiser[4] randomly selects some of the participants and displays their faces to other participants to simulate accidental encounters. In contrast, FreeWalk's approach provides a common virtual space for casual meetings wherein participants can move and meet by themselves. It doesn't promote any system-directed encounters. The participants' faces display on screen only when the bodies of their avatars meet.

2. Meetings with many people

In meetings such as parties, several tens of participants simultaneously exist in the same space. In such cases, it's almost impossible to use desktop videoconferencing systems, since they try to display the faces of all participants at once. Plus, even if it were possible, it would be very hard for users to comprehend the situation.

In FreeWalk, participants can freely change their locations and view directions. For example, they can wander around before they talk to someone else. They can also watch other participants.

Many systems realize a 3D shared virtual space. The Distributed Interactive Virtual Environment (DIVE)[5], a multiuser platform, lets people create, modify, and remove objects dynamically. This system has a script language to define autonomic behaviors of objects. Another multiuser virtual environment, Diamond Park[6], has a park, a village, and an open-air cafe. In addition, Community Place[7] integrates Virtual Reality Modeling Language (VRML) and has an online chat forum. InterSpace[8] supports audio and video communication for the experimental service CyberCampus, which features distance learning and online shopping. These systems aim to construct realistic virtual worlds containing many kinds of virtual objects such as mountains, oceans, buildings, artifacts, and so on.

We implemented a basic system to support casual meetings in a 3D virtual space that represents dynamic changes in people's locations during casual meetings. The role of 3D space in our system resembles the spatial model of interaction in Massive[9], a VR-based

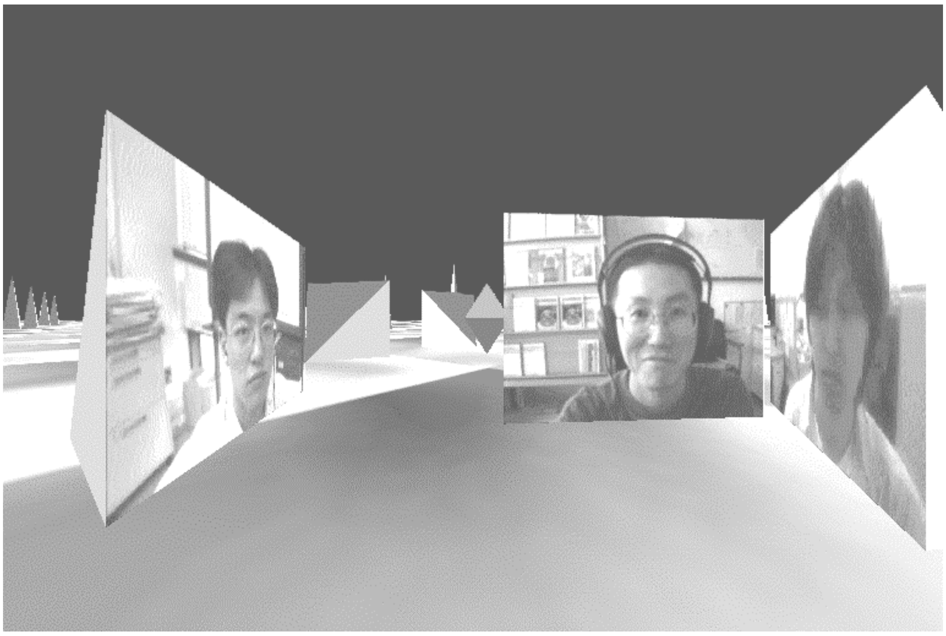


Figure 1. FreeWalk window.

(a) Participant A's view (b) Map of B and C's locations

Figure 2. Participant's view of community common area.

conferencing system with text and audio communication.

Since researchers haven't sufficiently investigated social interactions in 3D virtual space, we conducted an experiment to determine the characteristics of interactions in FreeWalk.

2. INTERACTION DESIGN

In this section we describe FreeWalk's design for interaction of the 3D community common area. We also discuss how FreeWalk supports casual group meetings.

2.1 3D COMMUNITY COMMON AREA

Figure 1 shows an image of a FreeWalk window. FreeWalk provides a 3D community common area where people can meet. Participants move and turn freely in the space using their mouse (just as in a video game). Locations and view directions of participants in the space determine which pictures and voices get transmitted.

In this 3D space, a pyramid of 3D polygons represents each participant. The system maps live

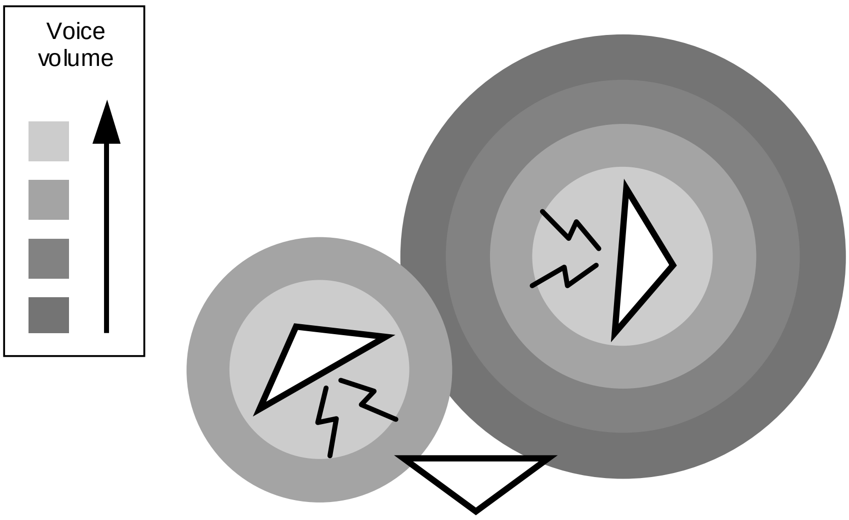
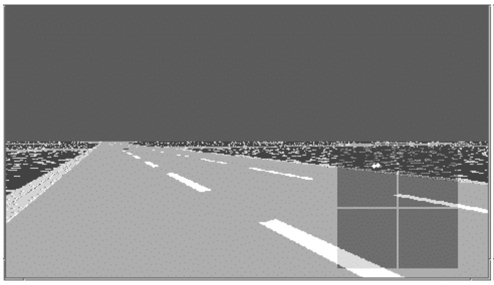
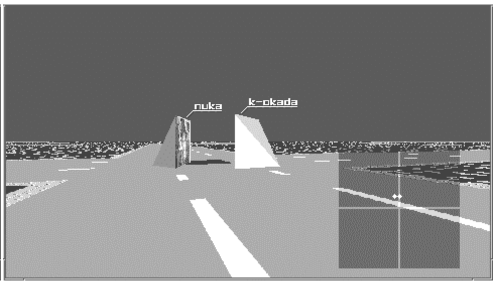


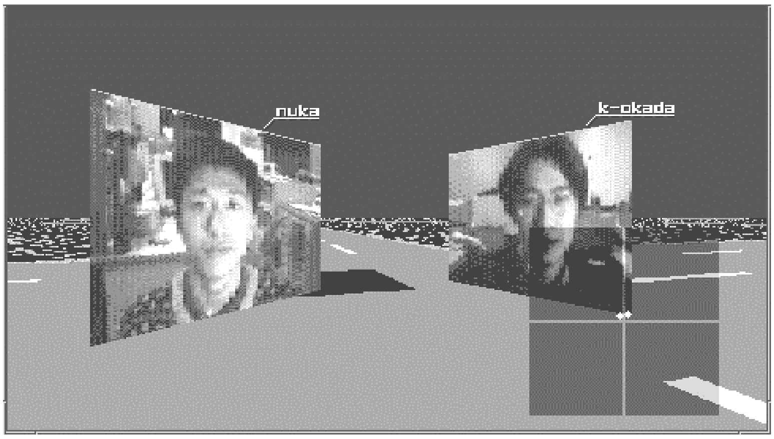
Figure 3. Voice transfer.



(a) Finding others on the radar screen



(b) Watching a talking pair



(c) Joining their conversation

Figure 4. Accidental encounter.

video of each participant on one rectangular plane of the pyramid, and the participant's viewpoint lies at the center of this rectangle. The view of the community common area from a participant's particular viewpoint appears in the FreeWalk window. Figure 2a shows participant A's view when participants B and C are located as shown in Figure 2b.

Participants standing far away in the 3D environment appear smaller and those closer appear larger. FreeWalk doesn't display participants located beyond a predefined distance. The system also transfers voices under the same policy—that is, voice volume changes in proportion to the distance between sender and receiver. See Figure 3.

2.2 SIMULATING CASUAL MEETINGS

In FreeWalk, meetings can start with an accidental encounter. Figure 4 shows an example of an accidental encounter, where the user finds others on the radar screen displayed at the right bottom corner of the window (Figure 4a), watches them to find out what they're talking about (Figure 4b), then joins them (Figure 4c).

Since distance attenuates voice, a participant must approach the others in order to talk to them. On the other hand, not only can the participants in the conversation hear the speaker's voice, but anyone in the neighborhood can listen. This mechanism forces people to combine actions and conversations in the space. People can smoothly join the conversation that attracts their interest, since they can guess the subject by listening to the conversation beforehand. People

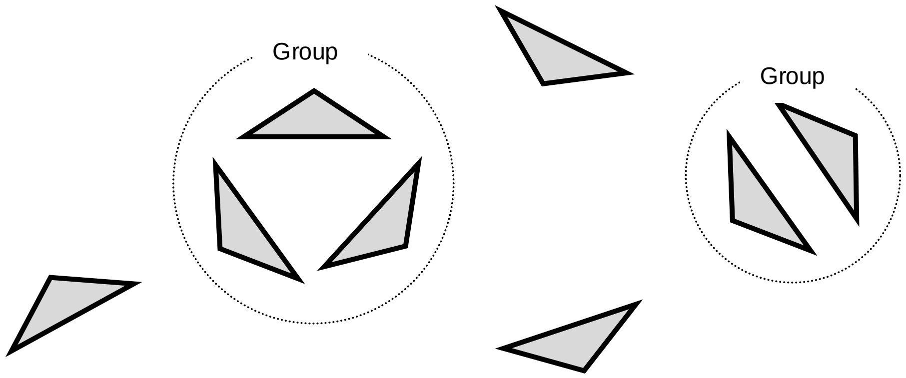


Figure 5. Meeting organization.

can exit a conversation by leaving a group and join a conversation by approaching another group.

2.3 ORGANIZING MEETING GROUPS

Desktop videoconferencing systems provide various functions to support the organizational behavior of participants, such as speaker selection. Although these functions let participants manage multiple conversation threads in parallel, they also damage the freedom we're aiming for. FreeWalk doesn't take this approach. Instead, it uses a common 3D space that promotes a casual feeling in communication.

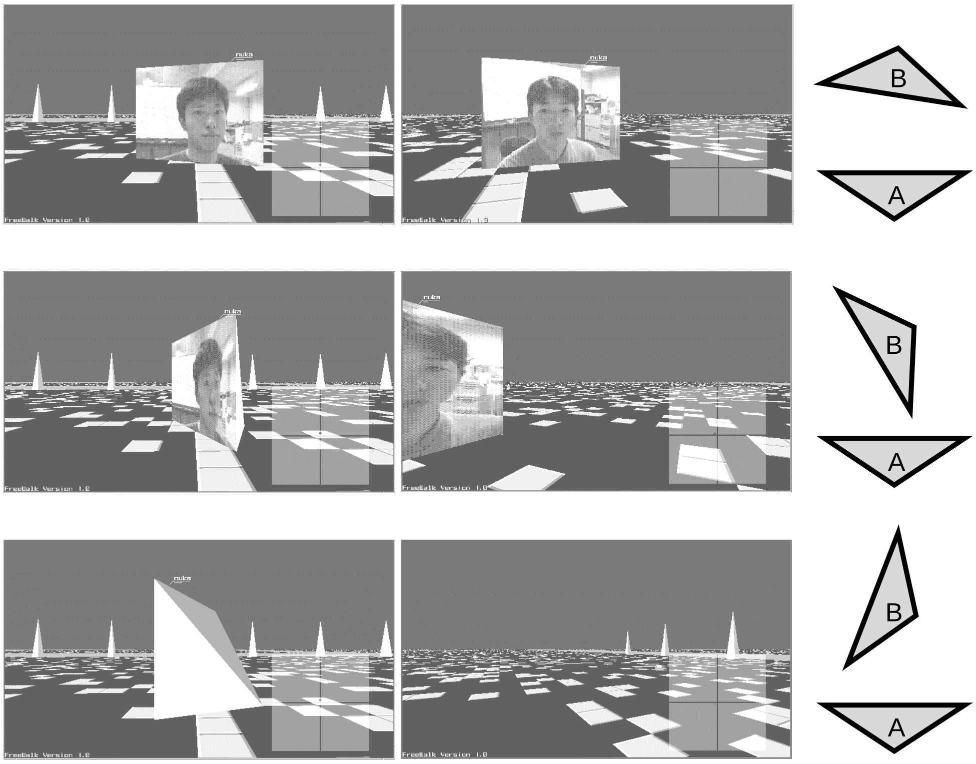
People form a group by standing close to each other to engage in conversation. Figure 5 shows this situation. Since voice volume attenuates in proportion to the distance between sender and receiver, people can have a confidential conversation by keeping away from others. If groups have enough distance between them, people in one group can't hear people in other groups. Therefore, participants can form separate meeting groups and not bother each other. This feature makes FreeWalk an effective tool for holding a party.

2.4 USING NONVERBAL SIGNALS

Space provides a context for interaction[10]. Spatial positioning is a nonverbal cue, which serves to communicate liking and disliking and attraction to a relationship. The orientation of a body and eye contact are used to start, sustain, and end interactions. These nonverbal signals are important in casual meetings since they smooth out and regulate social behavior. In the virtual space of FreeWalk, users can partially use these signals.

Interaction is controlled by a behavior that is changing body orientation, and communication becomes easy to do if this behavior is judged correctly[11]. The behavior that is turning directions of eyes, a head and a body is based on the structure of a human body. Turning behavior reflects emotional attitude toward others. The orientation of a pyramid represents the body orientation of a user in FreeWalk.

Since the participants' locations and view directions reflect a pyramid orientation, each participant can observe the distances or directions of other participants and what other people are doing from a distance. Participants can also observe others around them by turning their body. Figure 6 shows the view changes of participants A and B as participant B changes his direction in front of A.



(a) A's view of B (b) B's view of A (c) A map of the views

Figure 6. Changes of participants' views.

3. SYSTEM DESIGN

In this section we discuss FreeWalk's system design and implementation.

3.1 SYSTEM CONFIGURATION

The FreeWalk system consists of a community server and clients, each of which includes vision and voice processes. Figure 7 illustrates the interaction between the community server and clients.

When participants move in the 3D space using their mouse, the corresponding client calculates the new location and orientation, and sends them to the community server. The server then compiles this information into a list of client locations in the 3D community common area. The server finally sends the list back to each client for screen updating. Since only control information transfers between the server and the clients, the community server can efficiently maintain a global view of the ongoing activities in the community common area.

When a client receives the list of other clients, the client's vision system sends its owner's picture to the other clients. On receiving pictures from other clients, the vision system redraws the display based on the information in the list and the pictures received.

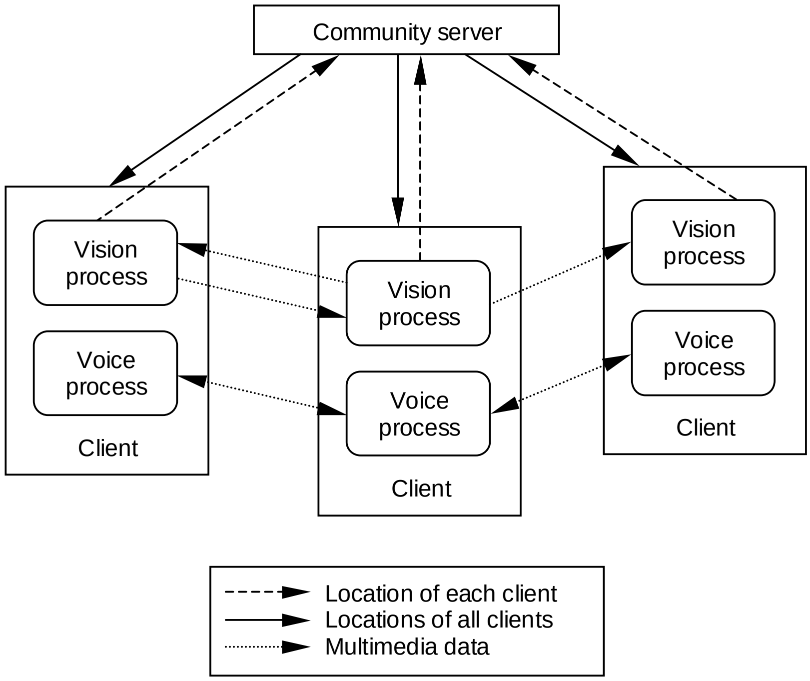


Figure 7. FreeWalk system configuration.

Because each client can't see all clients, it's not necessary for each one to send its picture to all others. Similarly, each client doesn't have to send full-size pictures to clients far away. FreeWalk uses these facts to optimize the bandwidth of video communication as follows:

- The sender adjusts the picture's size to the size the receiver needs.
- The client sends its picture to others who can see the client.

Figure 8 shows an example of a video transfer in FreeWalk. Since client A lies near client C, client C sends a large picture to client A. In contrast, client C sends a small picture to client B, because it's located far away.

Voice communication occurs in the same manner. FreeWalk clients don't send voice data to those clients located too far away to hear the participants' voices.

3.2 APPLYING VIDEOGAME USER-INTERFACE

Some videogames provide multiuser environments where users can control their *characters*. After investigating the similarities and differences between the two areas, we reach to conclude that videogames and videoconferencing systems can share user-interface design.

It is worth to point out that videogames utilize the 3D presentation. Most of them realize virtual spaces so that players can control their characters freely. We believe that the following features of videogame can be introduced into videoconferencing systems.

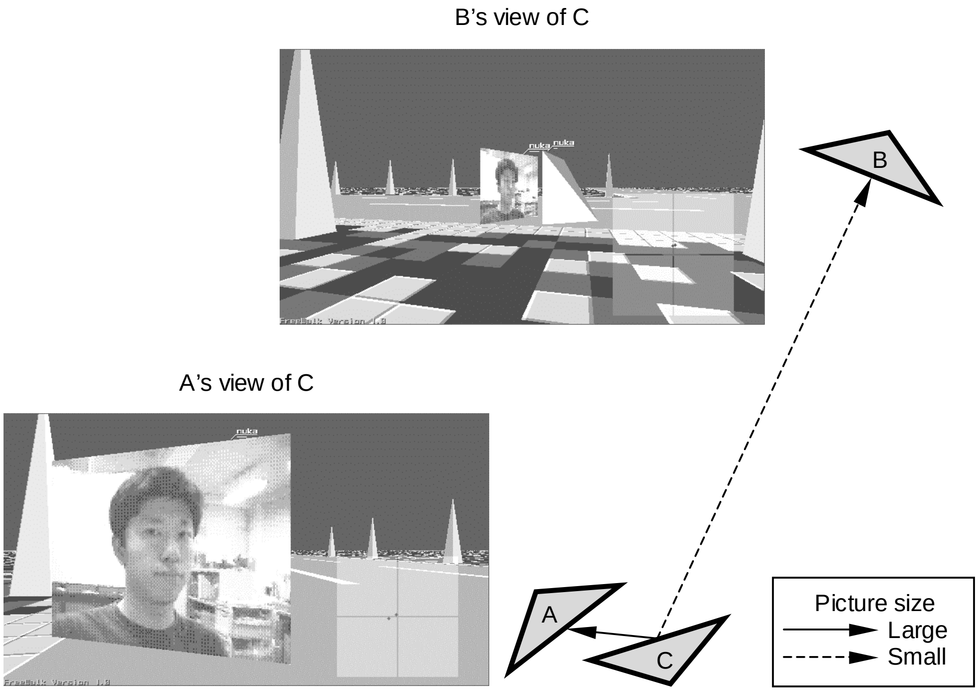


Figure 8. Video transfer among clients.

- *Displaying global situations in a 3D space*

  In videogames, since the move of characters is fast, and they are often time-bounded, most of them provide facilities for users to grasp global situations.

- *Running on a low cost machines*

  Though some of arcade games need special expensive input devices, most of videogames, especially game machines for home use (known as ``nintendo'' machines) or personal computers, do not. People can play them only with the low-priced general-purpose machines with a joy-pad, joystick, mouse or keyboard. Moreover, most of these devices are the standard attachments to such machines.

We applied the user-interface of such as action, shooting and racing games to the design and implement FreeWalk for realizing casual meetings in a network. FreeWalk imitates the user-interface of videogame in controlling the user's character and in grasping the surrounding situation.

3.2.1 Freely Walking in the 3D Space

Since the standard input device for a home game machine is joystick with several buttons, almost all videogames are designed for this device. Since one of the standard device of workstations is a mouse, the motion of users' pyramids is controlled by *X* and *Y* valuators of a mouse pointer during its left button is down. A user controls the orientation of the pyramid by a mouse so that the moving/turning speed is proportional to the distance between the mouse pointer and the center of the FreeWalk window. Since users can easily control the speed of moving/turning, they can run when the target is in a distance and slow down as the target becomes closer.

3.2.2 Grasping Situations in the 3D Space

Since the view angle in CRT is much narrower than that of human eyes, it is hard to grasp surrounding situations. Moreover, a human in the real world can easily look around by turning his/her head, but cannot do the same thing in the 3D space. Though virtual reality systems can simulate this by a head-mounted display (HMD), widely used machines do not equip it. In videogames, therefore, additional auxiliary indicators and viewpoint switching functions are introduced to help users to grasp their situations. From this observation, we implemented the following functions in FreeWalk.

- *Radar Screen*

  A radar-like screen indicates the simplified view of surroundings, including locations of characters. Figure 9 shows the FreeWalk radar screen. The radar screen can also indicate the volume of people's voice so that user can roughly know the activities within the groups.

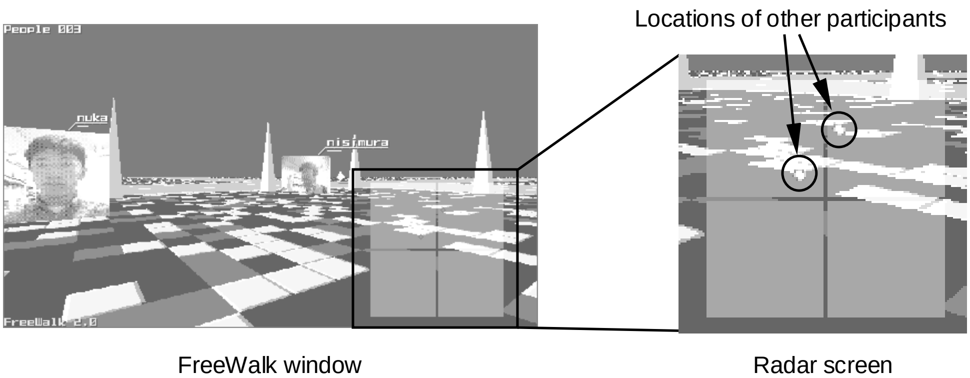


Figure 9. Radar screen.

- *Viewpoint Switching*

  In some situation, the bird's-eye view is more suitable for grasping the situation. The viewpoint switching function allows users to use multiple viewpoints to select an appropriate view. Figure 10 shows the bird's-eye view from the back of the user's character. This view enables the user to watch both the user's character and his/her

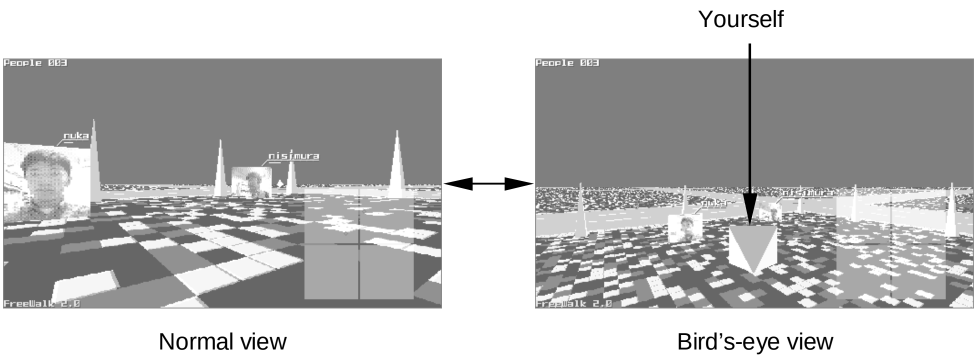


Figure 10. Switched viewpoint.

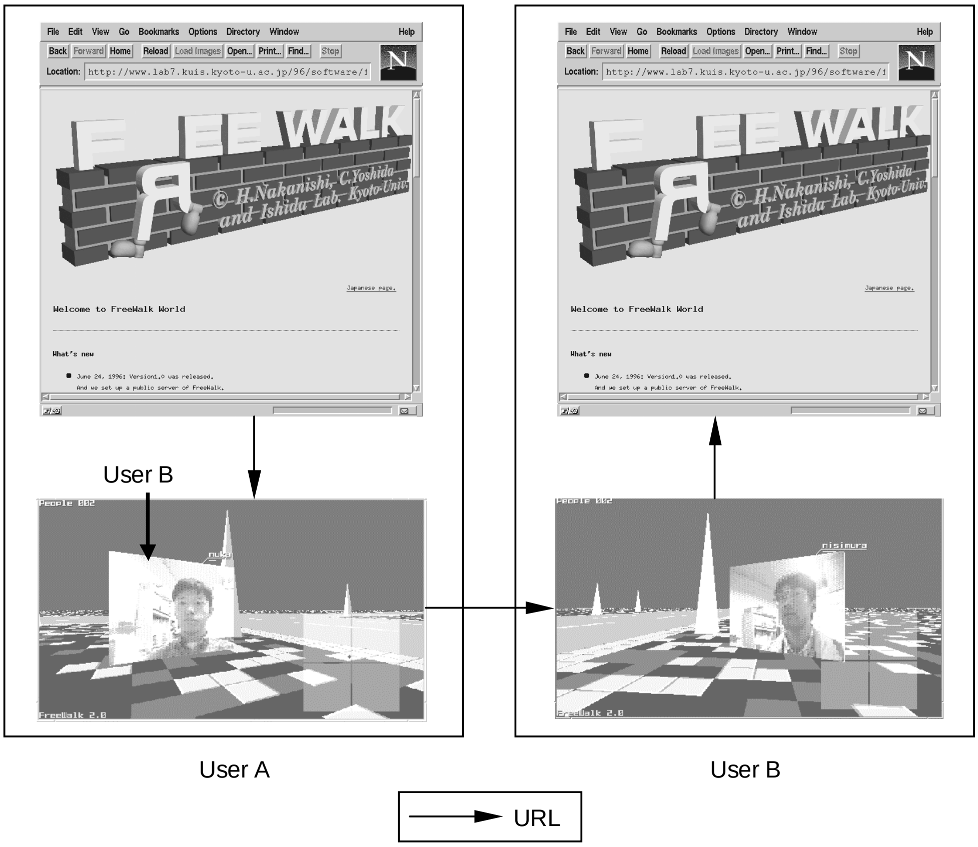


Figure 11. URL transfer.

surroundings. As a result, the user can have a better view of geometric relations among participants, and thus move easily than using the normal view.

3.3 SHARING WWW DOCUMENTS

In real life, people often talk with watching magazines or TV together to make their conversation richer in topics. FreeWalk has a function, which enables participants to generate topics by watching common information sources. A participant uses this function to make Web browsers of others displaying the same WWW document by transferring URL of his/her Web browser to others. Participants can watch the same WWW document to have a conversation in 3D virtual space with a rich stock of topics.

Figure 11 shows the route of URL transfer. In this figure, user A transfers the URL, which indicates the document in the user A's browser, to user B by pointing to user B drawn in user A's FreeWalk window. As a result, user B's browser displays the same document as user A's browser displays. Another possible way is to set up 3D objects corresponding to blackboards or bulletin boards in a 3D virtual space. But, by reducing the number of 3D objects to a minimum, the speed of 3D drawing is kept high in FreeWalk so that participants can move smooth in a 3D virtual space. Therefore, we did not choose this approach.

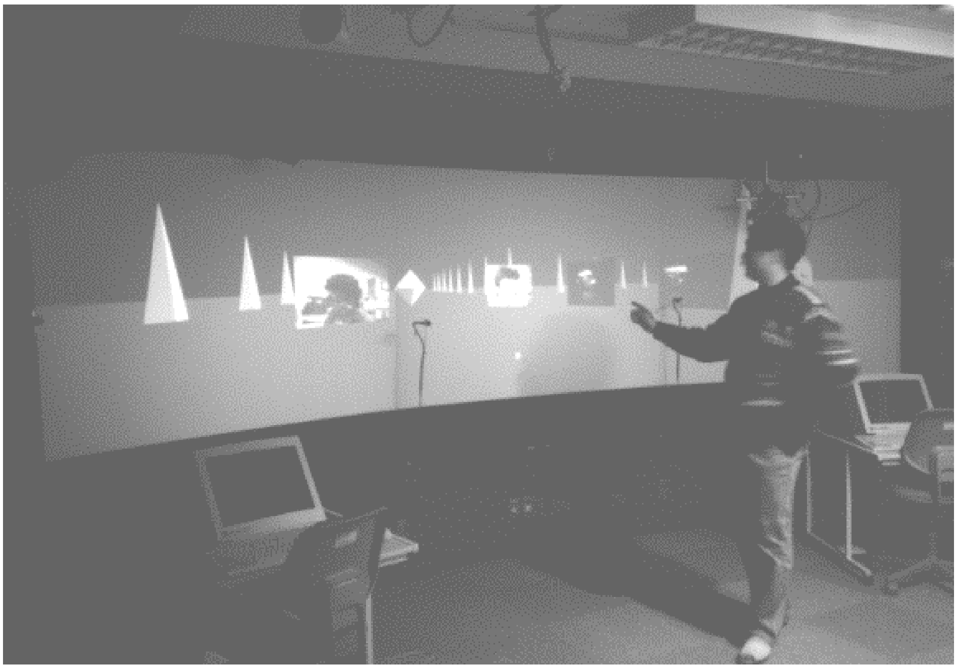


Figure 12. Virtual space on a large screen.

3.4 USING A LARGE SCREEN

We implemented the FreeWalk system on an immersive environment as well as on a desktop environment. We used a special room with a large-scale projector screen connected to a graphics workstation. Figure 12 shows a virtual space displayed on the large screen in the room.

Several people can simultaneously view the large virtual space displayed on the screen and talk to other people moving within that space. People using a desktop environment see the room represented as a larger pyramid. A large live video of the room visible in the space makes it easy to include the room and its participants in the virtual space.

4. PRELIMINARY EXPERIMENTS

4.1 EXPERIMENTS IN LABORATORIES

We organized six clients in different rooms of our department and validated our implementation policy. The major results we have obtained are as follows.

- Each participant could move according to his/her own will. The six people formed several groups from time to time. People reported that they could share the same space without confusion. Various behaviors have been noted so far, such as approaching a pair of participants talking to each other from a distance to secretly listen to their conversation, and chasing a moving participant while calling him/her to stop. Most of the participants enjoyed the experience due in part to its relaxed atmosphere.

- Most users felt that its user-interface is similar to videogames, intuitively understandable, and easier than other videoconferencing systems. There were a few people who found it difficult to control the moving speed using the distance between the mouse pointer and the center of the FreeWalk window. For this type of user, we added a mode where a user specifies only the direction of movement by the keyboard while the speed is set constant. Since the radar screen covers a wide area, it is not easy to distinguish adjacent participants. We are planning to make the range variable and customizable by users.

4.2 INTRANET EXPERIMENTS

We experienced an intranet meeting with FreeWalk in the event called *Open Campus* (the campus was open to public) held in Tohwa University. The visitors of the event joined FreeWalk meetings without any scheduling beforehand. The meeting continued about six hours and a maximum of 13 users participated simultaneously. As a result of investigating the log data, interesting behaviors of users in the virtual space were found as follows.

- *Most people move around the center landmark of the space*

  All the participants did not try to go far from the center. As population density around the center became high, network traffic exploded. This is because multimedia data of many participants are transferred to each client though he/she does not talk to most of them.

- *A group of people moved together*

  It was often observed that a couple of people moved together to a long distance, but seldom more than three. Some users reported that they wanted to ride a bus, because it is hard to move together.

- *Some people wandered from a group to group*

  In the latter half of the meeting, a number of participants who moved around decreased. Moving participants then wander from a group to group. It is very often observed that a couple of people face each other.

4.3 INTERNET EXPERIMENTS

We also conducted a preliminary experiment to verify whether our implementation of FreeWalk is competent to communicate through Internet. In this experiment, four users at Kyoto University in Japan and one user at University of Michigan in the United States joined the community server of FreeWalk at Kyoto University.

The frame rate of 3D drawing was about 10 frames per second, the same as in the previous intranet experiments. Though the delay of the live video was longer than that of an intranet, it was inconspicuous and did not affect the control of the player’s character much. The users reported they could hold a meeting as good as through an intranet. Sometimes the bandwidth between Japan and the United States forced us to lower the video frame rate to 4 frames per second. However, the users was still able to find others smiling through the live video.

The delay of audio was inconspicuous, too. However, the audio of the user at the United State sometimes became intermittent and the other users were unable to catch what he said while he could clearly hear the voice from Japan. Farther experiments found that the loss of UDP (Internet User Datagram Protocol) packet transmitting audio data caused the intermittent audio. The market-based approach to control quality-of –service[12] can be one solution.

Table 1. Functional Comparison

	FreeWalk	InPerson
Process of Joining	Enter a 3D virtual space voluntarily	Called by someone who has already joined
Maximum number of participants	Unspecified (practically, 20 or so)	7
Occurrence of conversation	Caused by participants' approach of their own accord	Caused by turning on the system by a coordinator
Meeting group	Multiple groups	Single group

5. COMPARISON OF COMMUNICATION ENVIRONMENT

There are many functional differences between shared virtual spaces and conventional videoconferencing systems. We compare these two kinds of communication environments to show the inherent advantages of shared virtual spaces for casual meetings. We took Silicon Graphics' *InPerson* (see http://www.sgi.com/software/inperson/) as the example of a conventional videoconferencing system and FreeWalk as the example of a shared virtual space. Table 1 shows the functional differences between these two environments.

- *Process of joining*

  In FreeWalk, the process used to join a meeting is just to enter the 3D virtual space provided. Each user selects which virtual space to enter when he/she starts up the system. The conversation protocol of InPerson inherits that of telephones: in order to hold a meeting between two persons, one should call the other via InPerson. If one wants to join the meeting, he/she needs to be called by someone who has already joined it. A newcomer cannot join an InPerson meeting freely.

- *Maximum number of participants*

  The maximum number of participants is seven in InPerson. This limitation is from the size of workstation displays. On the other hand, FreeWalk does not limit the number of participants, though if the number exceeds 20, the performance of the system becomes intolerable given the current condition of computer networks.

- *Occurrence of conversation*

  In FreeWalk, a conversation may be started by an accidental encounter while the participants are walking around the 3D virtual space. A conversation is started by participants' contact of their own accord. In the case of InPerson, conversation is started when the coordinator of a meeting turns on the system and contacts all participants.

- *Meeting group*

  In FreeWalk, participants approach one another to organize a meeting group. Participants can form multiple meeting groups simultaneously. In the case of InPerson, however, participants always form a single meeting group since everyone faces the others and hears the voices of the others.

6. INTERACTION ANALYSIS

Some earlier studies tried to compare communication aided by desktop videoconferencing systems to face-to-face (FTF) communication. Various characteristics of conventional video communication became clear through those studies[13]. However, the characteristics of the communication aided by a desktop videoconferencing system with a 3D shared virtual space remained unclear. In this section we show the characteristics of 3D communication compared to FTF and conventional video communications. We used InPerson as the conventional video environment and FreeWalk as the desktop videoconferencing system with a 3D shared virtual space.

6.1 HYPOTHESES ON CONVERSATION ENVIRONMENTS

We believe that 3D environments are more effective for casual communication than conventional video environment as follows.

- Participants using a conventional videoconferencing system tend to be strained and their conversations do not smoothly. This is because all their faces are always displayed and the system keeps everyone facing the others. A 3D virtual space eliminates this strain by giving them locations and view directions.

- It is impossible to reproduce communication with moves like real life communication in a conventional video environment. A 3D virtual space reproduces communication with moves by enabling participants to move freely.

Sellen compared communication in two video conferencing systems, Hydra and Picture-in-a-Picture (PIP), and in the FTF environment[14]. She found no differences among the three environments for conversation in terms of turns (transferring the initiative of speech), even though previous studies showed that more turns occurred in the FTF environment than in the videoconferencing environment. We expected that the number of turns might increase in casual meetings, so we analyzed the number of turns in our experiment.

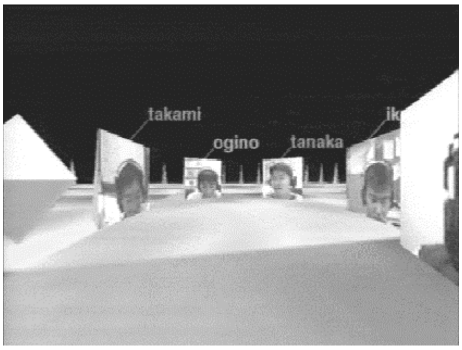
In another study, Bowers investigated how the movement of avatars coordinated with conversation in a virtual environment[15]. Results showed that the avatars' moves transferred the initiative of conversation. In 3D and FTF environments, the moves of people relate to their communication skills. In our experiment, we analyzed the moves of people in meetings.

Additionally, we counted the number of occurrences of chat and calculated the standard deviation of utterance. We thought a casual atmosphere might stimulate the occurrence of chat and change the amount of utterance of each participant.

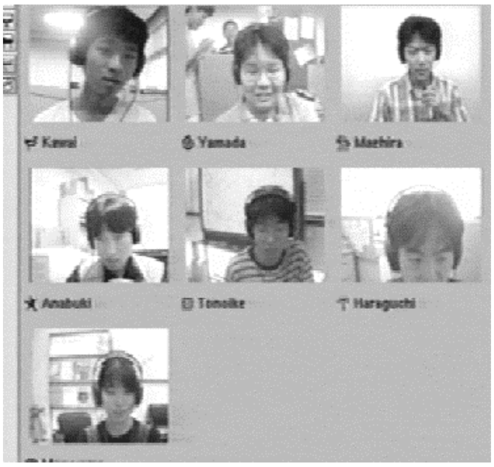
6.2 DESIGN OF EXPERIMENT

Twenty-one undergraduate students participated in our one-day experiment. We prepared three environments for conversation to compare FTF, conventional video, and 3D communications (see Figure 13). We set up seven SGI O2 workstations connected by a 100-Mbps Ethernet for the video environment (InPerson) and the 3D environment (FreeWalk). The meetings in the three environments consisted of three tasks as follows.

FTF



FreeWalk



InPerson

Figure 13. Three different environments for conversation.

1. *Agreeing on a group travel destination (Task 1)*

   This was a decision-making task. We made the participants decide where they would travel a month later. They were asked to pretend to be friends in high school days. Also, they did not have many chances to meet after they left the high school.

2. *Discussing social problem (Task 2)*

   This task was to shape ideas. They were asked to pretend that they attend the same lecture and had to hand in reports.

3. *Conversing freely (Task 3)*

   Participants had conversation without any guidelines.

We chose these tasks to examine various types of communication comprehensively. For each task, we told participants to organize three groups of seven people. Thus nine types of meetings took place. Each meeting lasted for 20 minutes. We didn't choose any chairpersons of the meetings in advance. Before performing the three tasks, the participants introduced themselves in each group so that they could memorize each other's faces and voices. They also practiced operating FreeWalk. The independent variables of this experiment were the differences between the environments and the tasks.

We collected experimental data using videotape recordings. During the FreeWalk and InPerson meetings, we recorded the screen images of the workstations on videotape recorders.

In FTF meetings, we recorded the scenes on 8-mm video. We reviewed the videotape pictures to record the start and end times of participants' utterances to create conversation records.

In addition, we collected the system logs of FreeWalk to find the pattern of moves in the 3D virtual space during meetings. The FreeWalk community server stores system logs in which it records locations and orientations of participants in a 3D virtual space. We made a tool called *SimWalk* to analyze participants' moves. SimWalk draws lines along the participants' moves and connecting their locations in sequence. It also can reproduce participants' behavior. Triangles corresponding to participants move to reproduce participants' moves in meetings. The triangles blink to indicate utterances of participants.

6.3 RESULTS

In this section we present the results of analysis of participants' conversations and moves.

6.3.1 Conversation

We organized the analysis results of the conversations into number of turns, standard deviation of utterance, and occurrence of chat.

1. Number of turns

This value represents the number of events. Each event transfers the initiative of talking from one person to another. The turn occurs when someone starts talking immediately after or while another talks. We didn't count cases in which someone stopped talking and started talking again after a brief silence.

Figure 14 shows the relation between the frequency of turns and environments. The frequency of turns equals the number of turns divided by the amount of utterances. The rankings of contributions of environments to the number of turns is characterized as:

FreeWalk > FTF ≈ InPerson

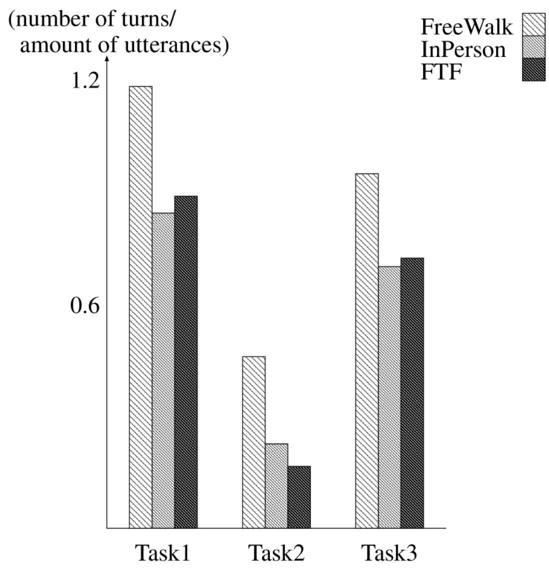


Figure 14. Frequency of turns.

The effect of the difference in environments showed that FreeWalk activated turns more often than InPerson and FTF.

2. *Standard deviation of utterance*

This value represents the standard deviation of the ratio of the total time of utterances of each participant to the total time of all utterances of all participants. Table 2 summarizes the standard deviations of utterance. It also provides the following ranking of environments for each task:

Task 1 FTF > InPerson > FreeWalk
Task 2 FTF > InPerson ≈ FreeWalk
Task 3 InPerson > FTF ≈ FreeWalk

Interestingly, the deviation remained the smallest in FreeWalk for all tasks. This means that the amount of utterances of each participant became equalized in FreeWalk.

Table 2. Standard Deviation of Utterance

	Task 1	Task 2	Task 3
FTF	13.93	19.19	14.07
InPerson	12.31	15.97	17.25
FreeWalk	9.28	15.45	13.45

3. *Occurrence of chat*

This value represents starting a conversation that doesn't contribute to accomplishing the task. Figure 15 shows the occurrence of chat in Task 1 and Task 2 in each environment. In Figure 15, the horizontal axis represents time, and each mark represents the occurrence of chat. Figure 15 shows that chat occurred more actively in FTF than in FreeWalk, while it seldom occurred in InPerson. The rankings of the contributions of environments to the occurrence of chat follow:

FTF > FreeWalk > InPerson

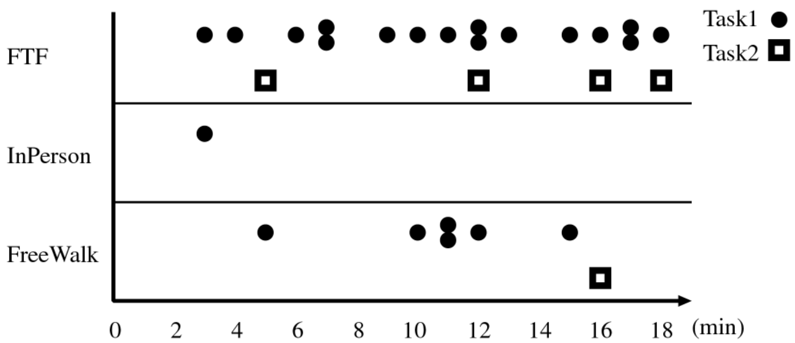


Figure 15. Occurrence of chat.

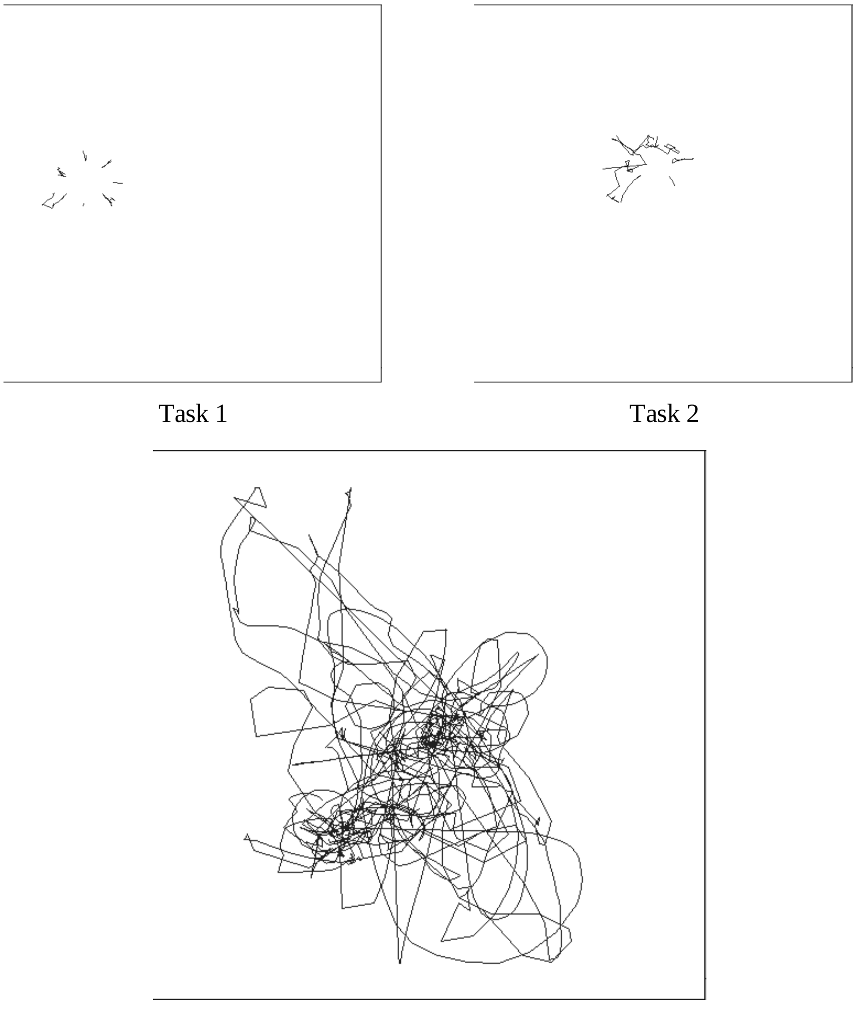


Figure 16. Pattern of moves in a 3D virtual space.

In FreeWalk, the atmosphere among participants might have been relaxed since they formed a circle to have a conversation, while in InPerson everyone faced the others.

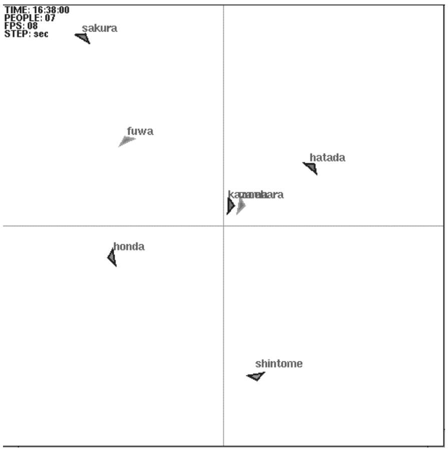
6.3.2 Participants' Moves

In FTF meetings, participants seldom moved after forming a circle to have a conversation. During InPerson meetings, everyone faced the others on the screen.

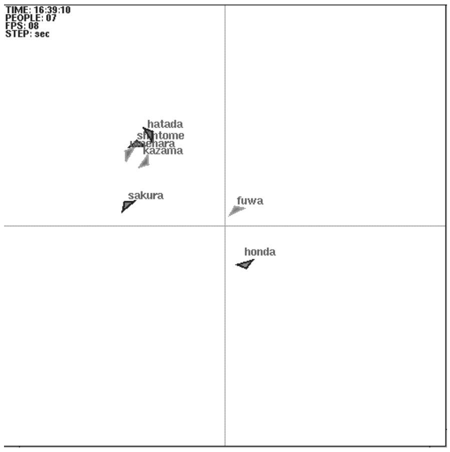
Figure 16 shows participants' moves during a 15-minute period in FreeWalk meetings. In Task 1 and Task 2, they seldom moved after forming a circle as in FTF. Unlike the other two tasks, they moved actively around the 3D virtual space in Task 3, as Figure 16 shows. In Task 3—free conversation—we observed the following behaviors:

1. Moving in a 3D virtual space

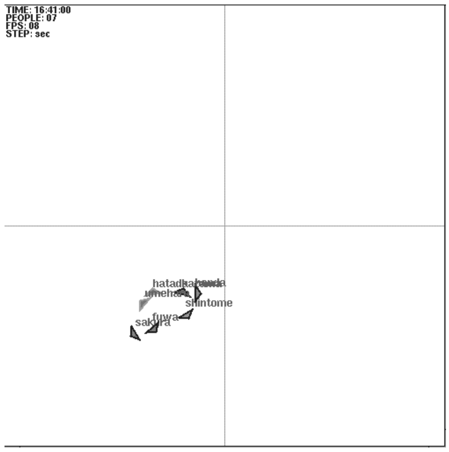
At the beginning of the task, participants moved actively. For example, they moved to the edge of the 3D virtual space and rushed toward others. The occurrence of



(a) Moving in a 3D virtual space



(b) Facing each other to greet



(c) Gathering to start conversation

Figure 17. Participants' moves in Task 3.

conversation was scarce. Figure 17a presents snapshots of SimWalk, which reproduces the participant's moves.

2. *Facing each other to greet*

In the middle of the task, participants faced one another frequently to greet. The lengths of conversations were short. We noted that some participants blamed others for approaching them when they tried to whisper to each other. You can see the participants greeting each other in Figure 17b.

3. *Gathering to start conversation*

Toward the end of the task, all participants gathered to converse. We noted that a certain participant ran about trying to escape from the meeting place since he was unwilling to talk, while another participant looked for someone else who had gone elsewhere. This situation is represented in Figure 17c.

6.4 DISCUSSION

As a result of our analysis, we categorized the effects of a 3D virtual space into two types. In the first type, we observed that 3D communication resembles FTF communication. Two primary characteristics exist: frequency of chat and behavior of participants. The second category, however, remains peculiar to 3D virtual spaces. These environments equalize the amount of utterances for each participant more than the other environments, increase the number of turns, and sometimes stimulate participants to move around to converse freely.

The results show the effectiveness of a 3D virtual space in casual meetings. The freedom of 3D virtual space lets participants enjoy their conversation, and its relaxed atmosphere stimulates participants into initiating conversations. On the other hand, participants having a meeting in a 3D virtual space tend to concentrate less than in the other environments.

7. CONCLUSIONS

FreeWalk supports casual meetings among many people. This system provides a three-dimensional (3D) community common area wherein participants can behave just as they do in real life. FreeWalk imitates the user-interface of videogames in operation and display.

We have conducted preliminary experiments by establishing FreeWalk on an intranet and the Internet. From the intranet experiments, we have verified that FreeWalk runs at practical speed with a large number of users. The Internet experiment showed that the implementation enables users to communicate through the Internet.

We have performed an interaction analysis to investigate the communication via FreeWalk, in comparison with that in a conventional videoconferencing system and face-to-face environment. The results show the effectiveness of a 3D shared virtual space in videoconferencing systems.

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