A 2D-3D Integrated Environment for Cooperative Work

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ABSTRACT

This paper proposes a novel tabletop display system for natural communication and flexible information sharing. The proposed system is specifically designed for integration of 2D and 3D user interfaces, using a multi-user stereoscopic display, IllusionHole. The proposed system takes awareness into consideration and provides both 2D and 3D information and user interfaces. On the display, a number of standard Windows desktop environments are provided as personal workspaces, as well as a shared workspace with a dedicated graphical user interface. In personal workspaces, users can simultaneously access existing applications and data, and exchange information between personal and shared workspaces. In this way, the proposed system can seamlessly integrate personal, shared, 2D and 3D workspaces with conventional user interfaces and effectively support communication and information sharing. To demonstrate capabilities of the proposed display system, a modeling application has been implemented. A preliminary experiment confirmed the effectiveness of the system.

Categories and Subject Descriptors

J.6 [**Computer-Aided Engineering**]: Computer-aided design; H.5.3 [**Information Interfaces And Presentation**]: Group and Organization Interfaces—*Collaborative computing, Computer-supported cooperative work*

General Terms

Design

Keywords

2D - 3D Integrated User Interface, VNC, IllusionHole

1. INTRODUCTION

This paper proposes a novel tabletop display system for natural communication and flexible information sharing. The proposed system is specifically designed for awareness support and integration of 2D and 3D user interfaces. Figure 1 shows the proposed system in use.

Human-to-human communication and information sharing are crucial for cooperative work. Information sharing means that information in the collaborative workspace is properly seen and manipulated by the participants. Collaboration is promoted by discussing such shared information. There are many types of information to share in collaboration including drawings, documents, maps, and maquettes. To establish an effective cooperative workspace, following issues need to be considered.

- Workspace layout for awareness support.
- Compatibility with conventional desktop environment.
- Support of various kinds of information.

First issue is a workspace layout. To share information, a table, a white board, and a large screen display are typically used in cooperative work. When a shared workspace is on the wall (e.g. a white board and a large screen), participants cannot see each other's faces and gestures while paying attention to shared information on the wall. In this setup, they cannot see information on the wall either while seeing each other. On the other hand, when participants sit around a table facing each other, it is easy to communicate by exchanging non-verbal communication cues such as facial expressions, poses, gestures and viewing directions. These cues play great roles in communication to attract attention. Attentions from non-verbal information are referred to as "awareness." With respect to awareness, it is useful to use a table-type screen [1, 2, 3].

Second issue is compatibility with a conventional desktop environment. When information is shared on the screen, it is important that the entire workspace is divided into a shared workspace and a number of personal workspaces, that information in the personal workspace can be presented in the shared workspace, and that shared information can be manipulated by any participant cooperatively. A shared workspace is always accessible by all users, encouraging discussion in collaboration. On the other hand, personal workspaces placed near to the shared workspace are said to have an important role in terms of independent activity and collaboration efficiency [2]. In addition, a personal workspace should be provided in a way that each participant can easily access and process information in it. In a typical meeting where each participant brings his or her own laptop computer, only a single computer screen is shared at a time and participants need to switch screens frequently. But each participant knows how to use his or her own personal workspace. To provide a better workspace, several studies have developed a collaboration system that seamlessly integrates a conventional desktop graphical user interface (GUI) environment with a shared screen[1, 2, 4, 5]. Some studies have developed a set

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(a) Proposed system in use

(b) A screenshot of the system

Figure 1: A tabletop envrionment.

of dedicated interaction techniques for shared information on the table[6].

Third issue is about variation of shared information. Shared information can be either 2D or 3D, according to the collaboration task. To support 3D information, a collaborative workspace is expected to present 3D (stereoscopic) images correctly to every participant so that the entity appears at a single location. Some studies try to integrate conventional computer environments into 3D workspace using augmented reality or mixed reality techniques[7, 8].

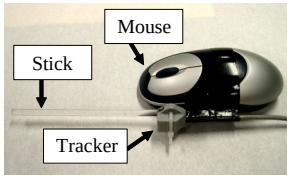
In this paper, proposed is a new cooperative tabletop system which integrates four types of workspaces; 2D, 3D, personal and shared workspaces. In the following, characteristics and functions of the proposed system are explained in Section 2. Section 3 describes an experiment and discussions. Section 4 describes details of implementation are given.

2. THE COOPERATIVE TABLETOP SYSTEM

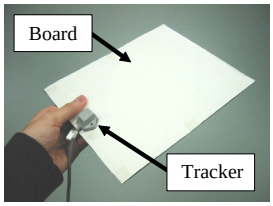
In this section, an overview of the proposed system is described. First, its display design to support 2D and 3D information is given. Then, its tabletop environment is explained that supports both a conventional desktop environment as a personal workspace, and a shared workspace. Finally, a modeling application is described to the capability of the proposed system.

2.1 A design of 2D-3D display system

(a) Entire display system



(b) Stick mouse



(c) Operation plate

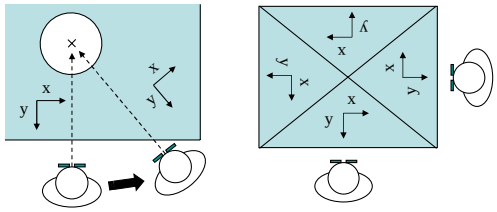
Figure 2: Display System.

Our system consists of an IllusionHole [9] to provide a 3D cooperative workspace, and another overhead projector to display a 2D workspace onto a mask panel of the IllusionHole as shown in Figure 2. A pair of stereoscopic images is displayed using a 60-inch IllusionHole whose hole diameter is 26 cm. Since IllusionHole's mask panel exclusively shows a pair of stereoscopic images to a user and hides those from other users, multiple (practically up to four) users can simultaneously observe the same 3D scene from their own viewpoints through a pair of polarized glasses with head tracking facility. Unlike a normal IllusionHole, our system utilizes a mask panel of IllusionHole for projection of 2D workspace. Note that a pair of polarized grasses is advantageous over a head mounted display (HMD) in terms of easy attachment and peripheral vision. Peripheral vision is important to recognize other participants' faces and gestures.

The proposed system is designed to display both 2D and 3D information. In this environment, if different devices are provided for 2D and 3D environments, users need to switch them repeatedly with physical and cognitive burdens. A stick mouse (Figure2(b)) is then provided which is seamlessly available in both 2D and 3D workspaces. A stick mouse works as a normal mouse when it is manipulated on the mask panel on which a 2D pointer appears (2D mode). On the other hand, when it is manipulated inside a cylinder-shaped 3D volume above the mask hole, it works as a 3D pointing device (3D mode) using a Polhemus tracker with six degree-of-freedom (6DOF). In the 3D mode, an arrow-headed 3D cursor appears at the tip of the stick in the 3D workspace.

An operation plate (Figure2(c)) is a plastic board with a Polhemus tracker with which a variety of 2D-3D coordinated functions can be performed. An operation plate is considered as a second, independent 2D workspace, and it also acts as a bridge between 2D and 3D workspaces. For example, a user can invoke and operate a 2D hierarchical menu on the operation plate, or select a 2D cross section of a 3D model for 2D editing at an arbitrary orientation by placing the board inside the model, or scoop a 3D object to move to the 2D workspace like a palette.

For a 2D image on the operation plate, a projection frustum is precisely adjusted to a real frustum defined by the overhead projector and the mask panel (see Figure 2(c)). A 2D image to be shown on the operation plate is rendered as a virtual plate in space at the position and orientation of the actual operation plate and is transformed with this perspective projection. As a result, any 2D image



(a) Circle (b) Partition

Figure 3: Rotation of mouse coordinates.

is projected onto the operation plate without distortion.

2.2 Table top environment

Figure 1(a) shows the tabletop environment in use. The tabletop environment is composed of a few standard Windows desktop environments (personal workspaces) and the rest of the screen (a shared workspace). A standard Windows desktop is provided to each participant as a scalable, movable GUI component. On the other hand, a dedicated GUI (tabletop GUI) is provided for the shared workspace. In the following, we describe the characteristics of the tabletop environment.

2.2.1 Tabletop GUI

A tabletop GUI is similar to a conventional desktop environment consisting of a mouse cursor, a pop-up menu and a desktop environment (Figure1(b)). A stick mouse and a keyboard are used as input devices. A mouse pointer is displayed corresponding to each mouse. A popup menu appears if a user clicks the right button of the mouse. A desktop environment in the tabletop environment is a normal Windows desktop environment. Since this mechanism is realized by a standard VNC protocol, participants can bring their own Windows environments they usually use into the tabletop GUI to utilize existing applications and data. In this way, the tabletop environment seamlessly integrates shared and personal workspaces.

2.2.2 Simultaneous input

In this system, every mouse and keyboard is connected to a single computer via USB connection. Each input device and its event is recognized and processed independently using raw Windows APIs. So users of this system can use arbitrary number (up to 127) of mice and keyboards independently. That is, multiple users can simultaneously manipulate GUI on the tabletop environment. For example, multiple users can use their pop-up menus and desktop environments in parallel by operating mice and keyboards.

2.2.3 Adaptive mouse coordinate system

When a user holds a mouse, he or she tends to maintain the relative position and orientation between his or her body and the mouse regardless of standing position. In a tabletop user interface, it becomes difficult to operate a mouse when the direction of the mouse is wrong side up. To solve this problem, it is necessary to rotate the mouse coordinate system according to user's standing position so that he or she can move the mouse pointer easily. In this system, user's eye position is used to rotate the mouse coordinate system based on following two different policies.

- **Circle**

  The mouse coordinate system is rotated so that its y-axis becomes parallel to a line connecting user's position and the center of the screen (Figure 3(a)). In this case, the mouse coordinate system rotates continuously.

- **Partition**

  The entire screen is partitioned into four areas according to screen edges. The mouse coordinate system is rotated discretely so that x- and y-axes are parallel to screen edges (Figure 3(b)).

In the tabletop environment, the mouse pointer and GUI components such as pop-up menus are dynamically rotated according to corresponding user's standing position. This function help users easily operate the tabletop GUI and distinguish right mouse pointers and GUI components.

2.2.4 Desktop environments

The desktop environment in the tabletop environment is not only used as a conventional personal space, but users can also use the desktop environment as a kind of shared workspace . That is, any user can operate any desktop environment and multiple users can share a single desktop environment. Figure 4 shows an example operation. In Figure 4(left), a user is operating a desktop environment with his mouse pointer in its boundary. In Figure 4(middle), the mouse pointer have left the desktop environment and is moving to the other desktop environment. In Figure 4(right), the user is now operating the other desktop environment. Based on the entry of the mouse pointer, an appropriate keyboard is chosen for key events. In this way, users can use their favorite applications simultaneously and seamlessly without the need for switching of input devices and computer screens.

2.2.5 Moving, rotating and scaling of a desktop environment

Manipulation of a desktop environment in the tabletop GUI is similar to that of a single window in a standard GUI. Users can move, rotate, and scale the desktop environment in the tabletop environment (Figure 5). The margin (border area) is set around each desktop environment. When the margin is dragged with a left button, the desktop environment is moved in the tabletop environment. To see or to show information in a desktop environment, users can simply move it closer to the observer. When the margin is dragged with a right button, the desktop environment is rotated around its center. This function is helpful to read information in a desktop environment. When the mouse wheel is scrolled, the desktop environment is scaled up or down. Using this function, a desktop environment of interest can be enlarged while an unnecessary one can be shrunk temporarily. An overlapped desktop environment can be moved front most by clicking its margin. A desktop environment can be hidden by using a pop-up menu.

2.2.6 Information transfer from desktop to tabletop

Information in a desktop environment (personal workspace) can be transferred to the tabletop environment (shared workspace). If a user copies a file in a desktop environment, the file is copied to a virtual clipboard of the tabletop environment. Note that an arbitrary file type is supported and multiple files can be copied at a time. For example, a file containing 3D geometry data can be copied from a desktop environment, and then shown at the center of the tabletop environment as a stereo image using IllusionHole's basic feature (Figure 6). First, the 3D object file is selected from folders on the desktop and copied. Then, the user moves the mouse pointer to the outside of the desktop environment and paste the file by using a pop-up menu. He or she can see the 3D object stereoscopically by

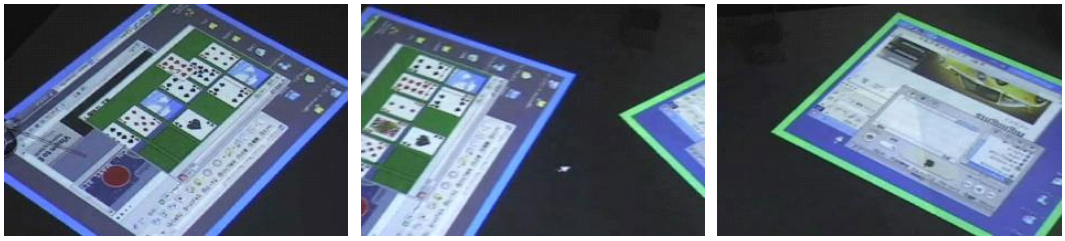


Figure 4: Operation between desktop environments.

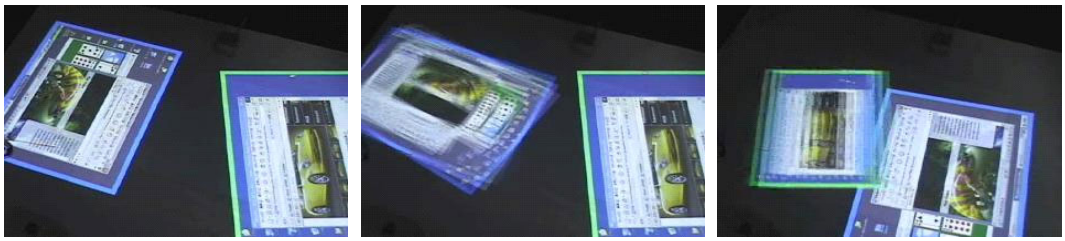


Figure 5: Translation, rotation and scaling of desktop environments.

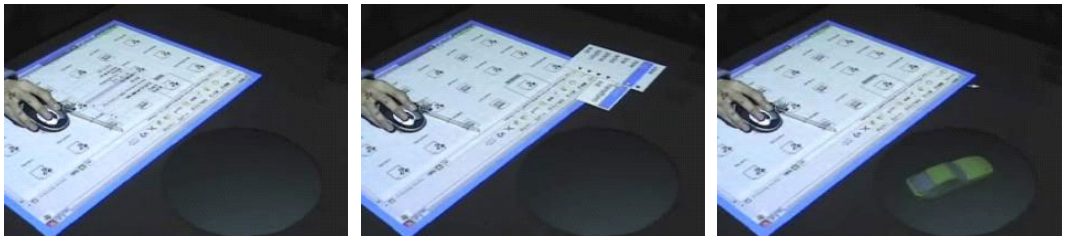
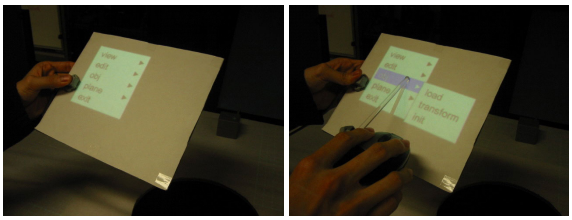
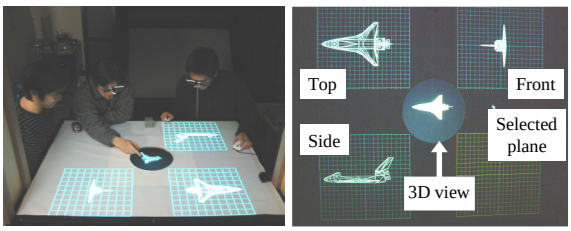


Figure 6: Information transfer from a desktop environment to the tabletop workspace.



(a) Displaying a menu (b) Selecting an entry

Figure 7: A menu on the operation plate.



(a) Cooperative modeling (b) Appearance of application

Figure 8: Prototype of a modeling application.

a pasting operation. In this way, desktop environments are seamlessly integrated into the shared space. As another way of information transfer, drag-and-drop feature is under development.

2.2.7 Menu operation on the operation plate

Normally, a user needs to place his or her mouse pointer on the screen to use a pop-up menu. But this is inconvenient when the user is working in the 3D workspace. So another way of using a pop-up menu is provided using an operation plate (Figure 7(a)). In this case, a tip of the stick mouse is used to select the menu item. A mouse pointer is shown at the foot of a perpendicular line connecting the surface and the mouse tip. As a normal pop-up menu on the mask panel, the mouse pointer can be used to select a menu item (Figure 7(b)).

2.3 Modeling application

To demonstrate flexibility of the proposed system, a modeling application has been implemented which tried to integrate 2D and 3D workspaces [12, 13]. The prototype modeling system supports cooperative modeling (Figure 8(a)) and provides a number of basic features found both in typical existing 3D CG modelers (e.g. orthogonal views) and in immersive modelers (e.g. head-tracked stereoscopic viewing) (Figure 8(b)). Some modeling examples using the prototype modeling system are illustrated below. Currently, Wavefront OBJ format is supported as a standard file format for import and export. A user is also able to create a new object in a number of ways, including revolution and extrusion.

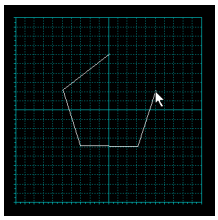
To make a revolution object, a user first needs to specify a cross

(a) Creation of body of rotation

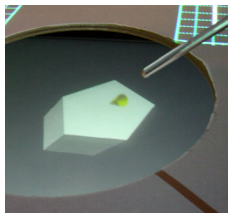
(b) Creation of sweep object

(c) Free form deformation

Figure 9: Object creation.

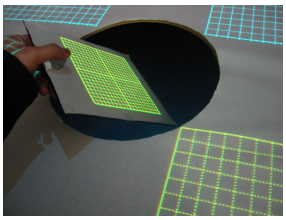


(a) Making a cross-section

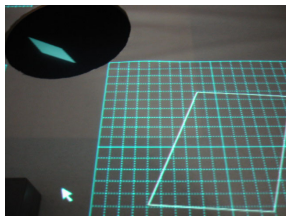


(b) Decision of sweep axis

Figure 10: A 2D-3D coordinated operation.



(a) Selecting a plane



(b) Operation on arbitrary plane

Figure 11: Selection of an optional view.

section by drawing an open line segment. A click of the mouse will add a vertex and a double click will end the operation (Figure 9(a) left). Note that the open line segment can be drawn both in 2D and 3D workspaces. The user then needs to decide a revolution axis, which is rendered in real-time with a mouse drag (Figure9(a) middle). The revolution axis is fixated with the lift up of the mouse button. The revolution axis can also be drawn both in 2D and 3D workspaces. Once the axis is fixed, a revolution object is made by rotating the open line segment around it (Figure9(a) right). To make an extrusion object, a user first needs to specify a cross section by drawing a closed line segment. A click of the mouse will add a vertex (Figure 9(b) left) and a double click will make the line segment into a surface (Figure9(b) middle). A closed line segment can only be drawn in the 2D workspace. A user then needs to decide an extrusion axis. With a mouse drag, not the extrusion axis but an extrusion object will be rendered in real-time. The object shape is finalized with the lift up of the mouse button (Figure 9(a)right). The extrusion axis can be specified both in 2D and 3D workspace.

Each object can be translated, rotated, scaled and deformed. Translation and rotation can be performed by a mouse drag both in 2D and 3D workspaces. When in the 2D workspace, a user is able to perform these operations with physical support of the panel surface. To deform an object, a user first creates a box-shaped control grid by a mouse drag to include the entire or a part of the object (Figure 9 (c) left). The control grid can be made either by mouse drags on two different orthogonal views, or by a mouse drag in space. Then, the user moves its control points by mouse drags in the 2D and/or 3D workspaces for deformation (Figure 9(c) middle and right).

In the prototype modeler, any object manipulations performed on the orthogonal views are simultaneously reflected to the stereoscopic view, and any manipulations in the stereoscopic view are simultaneously reflected to the orthogonal views. This interoperability enables 2D-3D coordinated operations. To create an extrusion object, for example, a user first draws a cross section on the 2D workspace (Figure 10(a)) then specifies a path of the extrusion in the 3D workspace (Figure 10(b)). To create a revolution object, a user first draws a cross section on the 2D workspace then specifies an axis of the revolution in the 3D workspace.

An optional view shows an object's cross section which is interactively selected by using an operation plate. In the plane-selection mode chosen by a pop-up menu, a cross section of a 3D object is dynamically shown on the operation plate and on the optional view area, based on the position and orientation of the operation plate in the 3D workspace. During the selection, a grid is projected onto the operation plate as a visual cue (see Figure11(a)). On the optional view, the same functions can be performed as on the top, side and front views (Figure 11(b)). In this way, an operation plate allows users to intuitively select a plane and manipulate an object. For example, a user is able to select a plane in an arbitrary direction onto which he or she creates a cross section using the plate, and then he or she can draw the section on the optional view.

3. PRELIMINARY EXPERIMENT

To verify the usefulness of the proposed system, a preliminary experiment has been conducted. After doing an experimental task, subjects answered a set of questionnaires. In the following, the experimental setup, results of subjective evaluation, and discussion are described.

3.1 Experimental setup

This experimental task requires a pair of subjects. First, subjects are given time to learn every manipulation needed. Then, a white 3D model of a space shuttle is loaded and displayed in the 3D

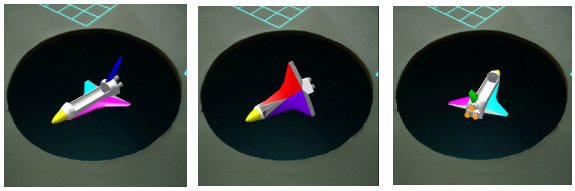


Figure 12: Color properties.

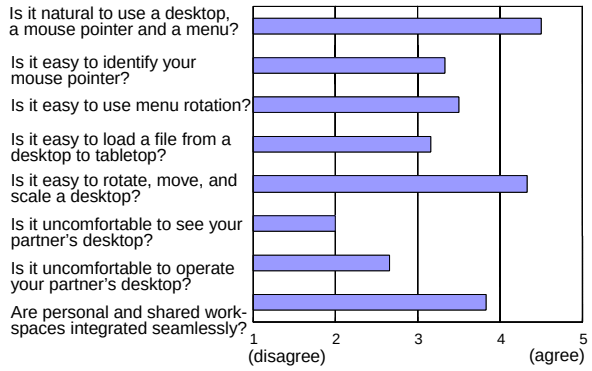


Figure 13: Comparison between personal and shared spaces.

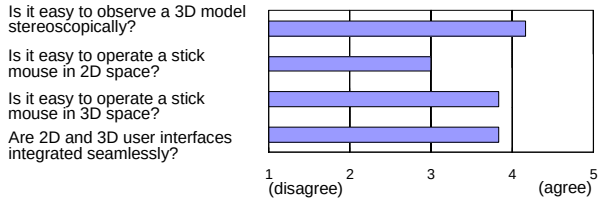


Figure 14: Comparison between 2D and 3D user interfaces.

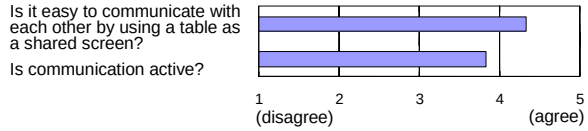


Figure 15: Communication.

workspace. The goal of the experimental task is to cooperatively find a pair of color property files of the space shuttle that have the same data among multiple candidates. In each of two desktop environments, there is a folder containing 12 sub-folders named "1" to "12". All sub-folders have a single color property file whose data are different but filenames are the same. Among all the data files in two desktop environments, only a pair of files contain the same data. Subjects need to apply a color property to the model one by one by copying a data file in a desktop environment and pasting it in the tabletop environment. They also need to rotate the model or change viewpoints to observe it carefully. Because the aim of the experiment is to get subjective evaluation, task completion time is not measured. Subjects do not need to accomplish tasks, and they answer a set of questionnaires. Each pair of subjects typically spent around 30 minutes.

3.2 Results of questionnaires

Three pairs of subjects participated in the experiment. After the expriment, subjects were required to answer a set of questionnaires on the scale of 1 (strongly disagree) to 5 (strongly agree). The questionnaires include eight questions about personal and shared spaces, four questions about 2D and 3D user interfaces, two questions about communication (total fourteen questions). Figures 13, 14 and 15 show average scores of the questionnaire results.

Subjects generally gave positive scores about seamless integration of personal and shared spaces, and 2D and 3D user interfaces.

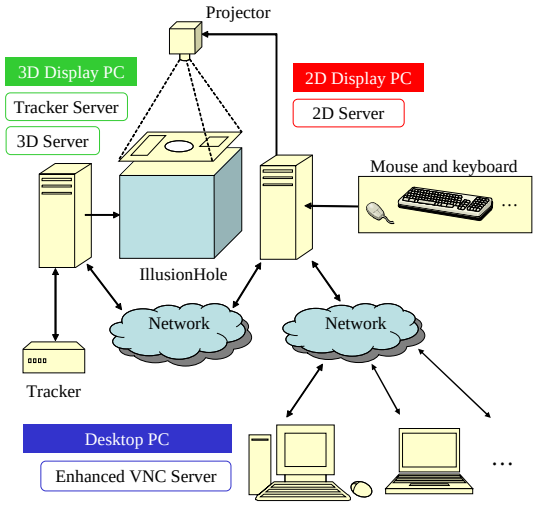


Figure 16: Hardware configuration.

Communication on the tabletop environment was also favored by subjects. Especially, it was confirmed that little training was required for subjects to understand how to use the tabletop GUI. They manipulated the tabletop GUI naturally without caring about their standing positions and orientations. Subjects had no complaints about the fact that their personal spaces can be seen and manipulated by other users. This is probably because of the nature of collaborative task of the experiment. However, in other situations, users may feel uncomfortable in a sense that the personal space is not a private space. We would like to pursue visualization strategies to provide not only shared or personal spaces but also private spaces (hidden by others).

Subjects favored being able to observe stereoscopic 3D models. 3D manipulation, however, was difficult for some subjects. To reduce the difficulty, visual feedback must be exploited more widely and carefully. Some subjects reported the stick and tracker of a stick mouse were cumbersome to use. The input device needs to be redesigned. Subjects also favored collaboration on the tabletop GUI. This indirectly suggests that the rotation feature of the personal space was successful, as a normal tabletop GUI demands frequent mental rotation.

Another problem of the prototype display is the support of the overhead projector, which is obstacle to users' view and thus users' motion, sometimes. This support needs to be removed by using ceiling mount suspension.

4. IMPLIMENTATION

In this section, described is implementation details of the proposed system. At first, the hardware configuration is explained. Then the overview of the software architecture is explained. Figure 16 shows the system configuration of the proposed system.

4.1 Hardware

The proposed system consists of a 3D server, a 2D server and a number of desktop PCs. The 3D server (Pentium 4 2.4GHz, 512Mbytes memory, nVidia GeForce4 4600) renders a 3D scene and controls Polhemus Fastrak that tracks 6DOF information of polarized glasses, stick mice and operation plates. A 2D user interface is shown on the mask panel and on the operation plates projected from an overhead projector placed above the IllusionHole. The 2D

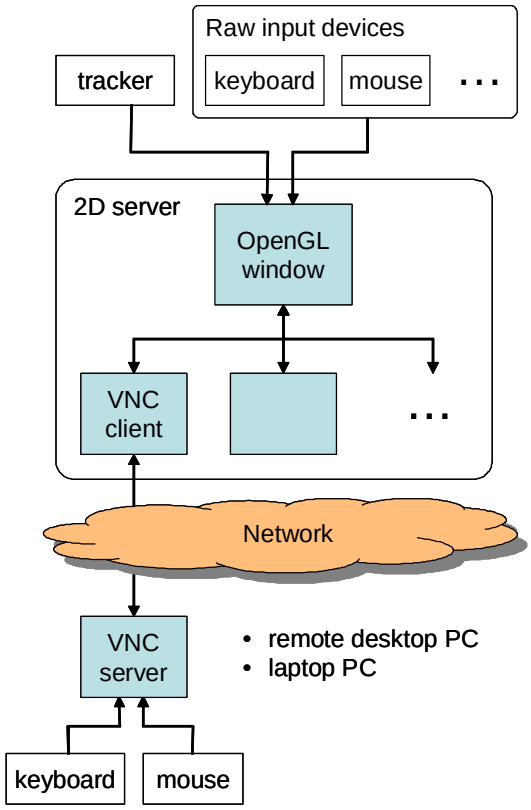


Figure 17: Software configuration.

server (Pentium 4 3.06GHz, 1Gbytes memory, nVidia GeForce4 4600) renders 2D images and controls stick mice. Using raw Windows APIs, several USB mice can be connected to the 2D server and independently controlled. Tracking information is sent from the 3D server to the 2D server, while mice information is sent to the opposite direction to maintain the consistency.

4.2 Software

The software architecture for the personal workspace is shown in Figure 17. VNC technology [10, 11] is employed to realize the feature. Although VNC was originally developed for remote control of a computer, it can also be applied for co-located collaboration [8]. An OpenGL window process and VNC client processes run on the 2D server. When the OpenGL window process accepts a connection request from a VNC server that runs on a remote computer, a new VNC client is invoked. The VNC client sends the OpenGL window process a remote desktop image received from the VNC server. The image is then transformed properly and rendered on the mask panel as a texture mapped rectangle. Following functions of VNC are specifically modified and extended.

- Multi-server and parallel processing.
- Translation from Windows DIB to OpenGL texture.
- Transfer files using the clipboard.

The prototype modeler can handle multiple USB mice with a single 2D server by using Windows' raw APIs. Multiple keyboards are also available with a single 2D server. All of these mouse and keyboard events received by the OpenGL window process need to be dispatched to a right VNC client (and a VNC server through it) properly. We would also like to implement a drag-and-drop feature. Since the OpenGL window process knows all clients' information, it will is easy to implement a direct manipulation interface for data exchange among personal workspaces [14].

5. CONCLUSION

In this paper, we have proposed a 2D-3D integrated environment for cooperative work. An IllusionHole provides a shared 3D workspace, while its mask panel is used as a versatile 2D workspace. Users are able to manipulate a shared 3D object both in the 2D and 3D workspaces seamlessly with special input devices such as a stick mouse and an operation plate. Not only these shared workspaces, a set of standard Windows desktop environments are also provided as personal workspaces, where users can use any applications and data. To integrate personal and shared workspaces, a dedicated GUI is provided. Through a preliminary experiment, we have confirmed the effectiveness of the prototype system. In the future, we would like to extend the functionality further and conduct a rigorous user study.

6. ACKNOWLEDGEMENT

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7. REFERENCES

[1] Rekimoto, J., Saitoh, M.: Augmented Surfaces: A Spatially Continuous Workspace for Hybrid Computing Environments; Proceedings of CHI '99, pp.378-385 (1999).

[2] Streitz, N., A., Geisler, J., Holmer, T., Konomi, S., Muller-Tomfelde, C., Reischl, W., Rexroth, P., Seitz, P., Steinmetz, R.: i-LAND: An interactive Landscape for Creativity and Innovation; Proceedings of CHI '99, pp.120-127 (1999).

[3] Ishii, H., Underkoffler, J., Chak, D., Piper, B., Joseph, E., B., Yeung, L., Kanji, Z.,: Augmented Urban Planning Workbench: Overlaying Drawings, Physical Models and Digital Simulation; Proceedings of ISMAR 2002, pp.203-211 (2002).

[4] Stefik, M., Foster, G., Bobrow, D., G., Kahn, K., Lanning, S., Suchman, L.: Beyond the Chalkboard: Computer Support for Collaboration and Problem Solving in Meetings; Communications of the ACM, Vol. 30, No. 1, pp.32-47 (1987).

[5] Mantei, M.: Capturing the Capture Concepts: A Case Study in the Design of Computer-Supported Meeting Environments; Proceedings of CSCW '88, pp.257-270 (1988).

[6] Shen, C., Vernier, F., D., Forlines, C., Ringel, M.: DiamondSpin: An Extensible Toolkit for Around-the-Table Interaction; Proceedings of CHI 2004, pp.167-174 (2004).

[7] Butz, A., Hollerer, T., Feiner, S., MacIntyre, B., Beshers, C.: Enveloping computers and users in a collaborative 3D augmented reality; Proceedings of IWAR '99, pp.35-44 (1999).

[8] Regenbrecht, H., Wagner, M., Baratoff, G.: MagicMeeting - a Collaborative Tangible Augmented Reality System; Virtual Reality - Systems, Development and Applications, Vol. 6, No. 3, pp.151-166 (2002).

[9] Kitamura, Y., Konishi, T., Yamamoto, S., Kishino, F.: Interactive stereoscopic display for three or more users; Proceedings of SIGGRAPH 2001, pp. 231-239, (2001).

[10] RealVNC; http://www.realvnc.com/.

[11] Ultr@VNC; http://ultravnc.sourceforge.net/.

[12] Forsberg, A., S., LaViola Jr., J., J., Zeleznik, R., C.: ErgoDesk: A Framework for Two- and Three-Dimensional Interaction at the ActiveDesk; Proceedings of IPT '98, (1998).

[13] Yoshimori, H., Matsumiya, M., Takemura, H., Yokoya, N.: Combination of two- and three-dimensional space for solid modeling; Proceedings of SIGGRAPH 2000 Conference Abstracts and Applications, p.191, (2000).

[14] Rekimoto, J.: Pick-and-Drop: A Direct Manipulation Technique for Multiple Computer Environments; Proceedings of UIST '97, pp.31-39, (1997).