

Perspective Layered Visualization of Collaborative Workspaces

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ABSTRACT

Visual shared workspaces will be always staying on users' screens in the near future. Users will be moving frequently between their personal workspaces for personal and asynchronous work and shared workspaces for communication and synchronous cooperation. Also the system should supports users' everyday awareness of co-workers. For supporting such situation, this paper proposes a new technique to visualize workspaces as a set of layered virtual screens in three-dimensional space. In this way, groups' shared spaces are shown as background of users' personal spaces like as looking from a top personal layer down to a bottom public layer. In conventional groupware, user's workspace is divided into some shared spaces and a personal space to show all of them simultaneously, so the size of the personal space is very restricted. This layered perspective visualization alleviates this problem and also supports users' awareness by always showing shared spaces in background.

Keywords

Shared workspaces, layered workspaces, virtual desktops, awareness, perspective view, 3d user interfaces, information visualization, background, VNC, CSCW, groupware

INTRODUCTION

Computer supported cooperative work (CSCW) will be brought into your everyday working styles in the near future. Nowadays many workers are already working on their personal computers, and the computers are connected with high-speed networks. After this, such networks will become more high-speed, then usually you will be using some video conferencing system for a bit of communication, and documents and materials will be managed in shared databases, which may have some graphical interfaces.

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As CSCW or groupware systems become widely used in your everyday work like this, evolutions of user interfaces towards supporting such situation will also be required. In this situation, two types of software can exist simultaneously on your computers: personal application software already used for many years, and groupware supporting cooperation and awareness in various new ways.

We think that these two types of software should consist of an integrated environment that allows users to frequently switch between them and to distinguish them from each other. Users will move frequently between personal software for conventional and asynchronous work, and collaborative software for communication and synchronous cooperation. In addition, users will have to surely understand in which sharing level they are working and which type of software they are using.

Furthermore, supporting users' awareness is considered very important in such everyday environments [5, 8]. Accessing everyday information, such as being aware of what your neighbor workers are doing and what messages are posted on your bulletin boards, is required for users to carry out collaborative work much smoothly. For example, the awareness, such as of the data modification or the activities of co-workers, brings group's shared understandings about the state of their work. Such understandings make communication among users more smoothly and the assignment of tasks more reasonable.

In order for users to share their information and support their own awareness, synchronous groupware realize visual shared workspaces established on the display areas of computer screens. Such shared workspaces, which are often implemented with windows of GUI (graphical user interface), may hold some shared documents and shared canvases. The system allows multiple users to access those shared information synchronously, and make aware of other participants' activities with some visual effects.

In the future, visual shared workspaces will be *always staying on your desktop*, so user interfaces of everyday groupware will be like current synchronous groupware,

because synchronous groupware are more concerning on awareness and visual interfaces than asynchronous ones.

This paper proposes a new information visualization technique for such environment of groupware systems. In this way, the system utilizes a background of a personal workspace to show shared workspaces, and moreover visualizes workspaces as a set of layered virtual screens with three-dimensional perspective technique.

VISUAL SHARED WORKSPACES

Previously in order to show shared information and shared workspaces to users, the techniques in Figure 1 have been widely used.

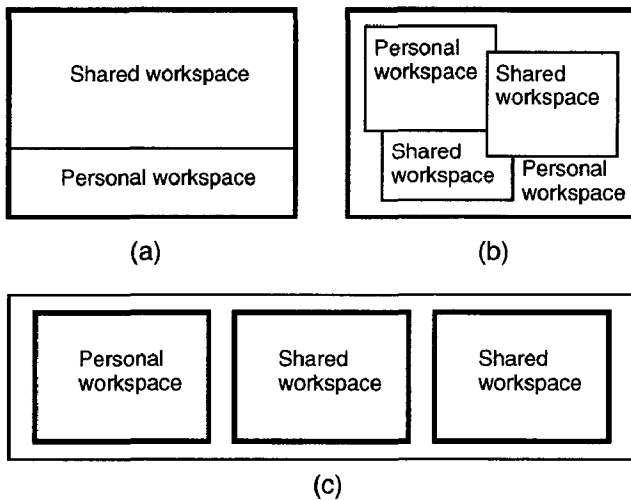


Figure 1: Techniques for visual shared workspaces: (a) tiling (b) windowing (c) virtual desktops.

Figure 1 (a) depicts a type of tiling method. This type of method shows both user's personal space and shared spaces simultaneously by dividing a screen or a window to several regions. However, in this way, quite a large area is used for showing a shared space, so the size of the personal space is very restricted.

Although this method can be adaptable for the applications that need to show shared spaces only on users' request, this is not suitable for the situation of our proposal: the new collaborative environment which shows shared spaces always staying on users' screen and thus enables users to be aware of co-workers' everyday activities.

On the other hand, Figure 1 (b) depicts a type of (overwrapped) windowing method. In this way, each shared space, or application software, is individually shown as a single window and can be moved freely by the user. Consequently, personal spaces and shared spaces are completely integrated and thus become seamless.

This method, however, may bring some confusion to users, since traditional personal applications and new collaborative applications are hardly distinguishable. All the

time, to prevent operational confusion, users have to be conscious of on which workspace each window exists. Also for example, users may configure privacy settings only concerning their personal space, but it can be difficult for the system to provide visual interface of intuitive configuration in such a completely seamless visual aspect.

Thus workspaces should be divided according to sharing levels of information, like real world offices that consist of private spaces, such as workers' private rooms, and public spaces, such as meeting rooms and library rooms. We think such spatial division and visual effects can be very comprehensive to provide users' security and privacy.

From these reasons, some conventional groupware systems support the method depicted in Figure 1 (c), which realizes personal spaces and shared spaces as different virtual desktops and shows one of them by users' selection. This method is often called the room metaphor. In this way, both problems of limited screen space depicted in (a) and operational confusion depicted in (b) are solved and users can frequently switch both types of workspaces

However, this method is not suitable for supporting user's awareness, because shared spaces and personal spaces cannot be simultaneously staying on the same computer screens. Therefore, this method is not suitable to realize environments for everyday collaborative work.

In summary, a collaborative environment for everyday work should provide the following features that past various groupware systems could not support simultaneously.

- Supporting users' everyday awareness of modification of shared information.
- Indication of sharing levels of shared information to prevent operational confusion.
- Allowing co-existence of and smooth switch among shared work and personal work.

To realize these features, we think that the system simultaneously visualize shared spaces and personal spaces into a visually integrated and also distinguishable appearances.

NEW WORKSPACE VISUALIZATION

In this section, we propose a new visualization technique that utilizes a background of a personal workspace as shared workspaces [20]. Moreover, we consider the hierarchical and layered architecture for shared workspaces, and propose the new pseudo-three-dimensional perspective visualization for the layered workspaces.

Background as Shared Workspaces

We propose a visualization that utilizes a background of a personal workspace to show shared workspaces. Thus frequently used personal applications are shown closer to users

than groupware supporting awareness and synchronous co-operation. Because this technique does not require certain screen areas for shared spaces, the system can always show shared spaces even if the screen spaces are limited.

In this way, users can switch between personal work and shared work without any special operations, because shared workspaces are always viewable and operable. Manipulations against objects in the background of the ordinary desktops mean immediately operations against shared objects in the shared workspaces. Therefore, users can carry out their work with easily and frequently move between personal spaces and shared spaces.

Furthermore, the system should provide the feeling that shared spaces are located really in back of personal spaces. If the system shows shared objects in background as they are with the original appearance, users hardly distinguish them from personal objects and might feel confusion of operation. So, to tell sharing levels of information clearly, the system visualizes shared spaces look farther from users than personal spaces.

Background Awareness

This conception of the background workspace can transmit awareness information properly, because it can show shared information and their modification always in background (indeed as screen background). Users can be aware of modification of shared information by other workers, even when users are not using shared applications.

The awareness is, in the field of CSCW, a conception of being unconsciously aware of other person's behavior and activities, and awareness often naturally brings about conscious communication.

Shared workspaces can be shown when users start their computers. If users configure so, they do not have to launch special application or open certain web pages to learn modification of shared information. Therefore this technique can be a basic interface platform for supporting users' awareness.

On the other hand, conventional visualization techniques of shared workspaces have allowed users to either show or not show shared spaces, so those visualization systems are not suitable for the collaborative environment of our proposal. The system should show shared workspaces always staying on users' screen and thus enables users to be aware of others' everyday activities.

When users spread many materials on their personal workspaces, the background workspaces are hidden under them, so the awareness of other users' activities becomes reduced. To cope with this problem, we propose that the system displays shared workspaces instead of screen savers. In the real world, we are often unaware of surrounding information such as voices when focusing some interesting work; nevertheless, in an every break of work, we view over

and can be aware of such co-workers' activities.

Multi-Layered Architecture

A screen background is not limited for using only a single shared layer of workspace. Workgroups in the real world sometimes make inclusive relationships more than two levels. In such case, shared information are managed under also more than two levels. So, there are some situations that only two layers (personal layer and shared layer) are not sufficient in a collaborative workspace.

In general, multi-user operating systems and database systems manage their resources in hierarchical ownership of users. Such hierarchical ownership is used with access controls to provide basic security. In the UNIX file system, for example, each file or directory has a owner and a group owner, so ownership and access rights of each resource are managed under three levels: user, group, and everyone.

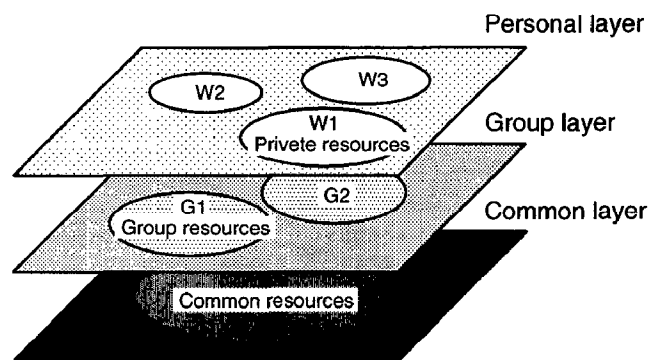


Figure 2: Multi-layered architecture for workspaces.

According to such hierarchical ownership, collaborative workspaces can be represented as multi-layered structures like as in Figure 2 [25]. Although users are often working in their personal workspace, they sometimes need to refer to information also in the workgroups that they belongs to, and also in larger groups that the workgroups belong to. For simplifying the problem, hereafter, we go with the example of this three-leveled layered workspace and call each layer, respectively, personal (private) layer, group layer, and common (public) layer.

For example, if workers are highly independent of one another and take great responsibility for their work, they do not need to see the progress of others' work. Therefore, at least only outputs that the others have generated are shared in their workgroups. In this case, it may be desirable for users to be ensured that their own working environments have minimum interference from the others.

In addition, any document is often used in its proper workspace; address books are often used in personal workspaces, and presentation materials are often used in public workspaces. So, automatically opening a document in its proper workspace can be useful feature. We call the

conception default workspace of shared information. Of course, in this way, document permission should be also considered for security and privacy.

3D Perspective Workspace

Based on this conception of the layered model of workspaces, the visualization technique of the background workspace described earlier can be extended to the three-dimensional perspective workspace.

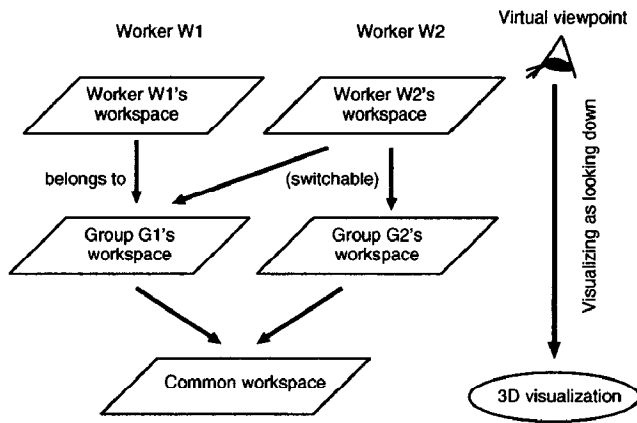


Figure 3: The visualization of layered workspaces.

This visualization shows a workspace from the viewpoint of each worker in Figure 3 like as looking from a top personal layer down to a bottom public layer. Therefore, the layered workspaces are shown as layered virtual screens in three-dimensional display (Figure 4). Each window of application software is located according to its sharing levels.

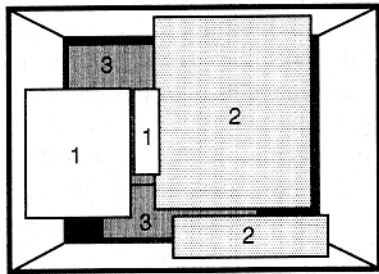


Figure 4: The perspective layered visualization: (1) on personal layer (2) on group layer (3) on common layer.

In other words, this visualization utilizes the visual parameter of depth on a screen for representing the sharing level of information, since the more widely shared information are visually located on the further positions from users. Although it is considered a three-dimensional visualization, it can be implemented with pseudo-three-dimensional graphics using combination of shrinking and overlapping of screen images.

Displaying information that is frequently accessed or referred by users at successively closer positions is a known technique [15] of three-dimensional information visualization [6]. In that field, various methods for showing information spaces on limited sized screens have been proposed, and the degree of interest (DOI) is an important conception. It can be considered that frequently accessed information has a high degree of interest. Such visualization software show the more frequently accessed information more visibly according to users' DOIs of information.

In three-dimensional visualization, the perspective technique is mostly utilized for representing users' DOIs [7, 15]. We think the conception of visualizing information according to their DOIs, or degrees of reference, is useful for transmission information concerning users' awareness. Personal workspaces will be more referred and manipulated by owners than shared workspaces, so it is natural to visualize personal information closer than that of group.

In collaborative workspaces, like surrounding information of the real world, transmitting users' awareness information with proper intensity is effective for collaboration and communication [10]. In the real world, when users are centering on something important, they might not be aware of others' gazes or auras. More, bulletin boards or televisions in public spaces are showing such background information in relatively weak intensity.

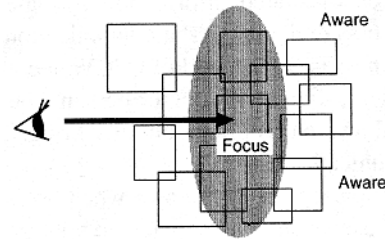


Figure 5: A worker can change the focus level in work.

The visualization that we propose is very suitable for purpose of such awareness support. The conventional groupware systems show shared information only when users request. We propose the visualization that can show shared information and their modification always in background with perspective effect to tell sharing levels of information and to control intensities of them (Figure 5).

Traveling in 3D Workspaces

This visualization three-dimensionally locates workspaces, so three-dimensional moving operations, such as forward, backward, rightward, and leftward movements, become the metaphors of changing users' current workspaces. We think that these operations are very intuitive for users, because, on their screen, these operations can be performed with effective visual feedback.

A worker often belongs to more workspaces than one including a personal workspace and a few group workspaces, because generally workers may belong to several workgroups simultaneously. CSCW systems should support users' intelligible switching from one workspace to another, and in the user interface of visual shared workspaces, the switching operation should be done also with visual and graphical operations.

As the Figure 6 shows, when users want to mainly deal with their group level information, they may move forward in the three-dimensional space. Then, their personal workspaces become invisible on computer screens and the group workspaces are shown on top of screens. Thus, it becomes easy for users to deal with the group level information. Furthermore, users can move more forward for dealing with public workspaces, and backward for their personal spaces again.

Also in the visualization, users' rightward and leftward shifts are metaphors of switching group workspaces that they belong to. Users can switch workspaces with moving horizontally on the same level. Although this feature provides almost same function as selection of virtual desktops in conventional systems, it provides the merit of integrating inclusive relationships and parallel relationships of workspaces by the same spatial metaphor.

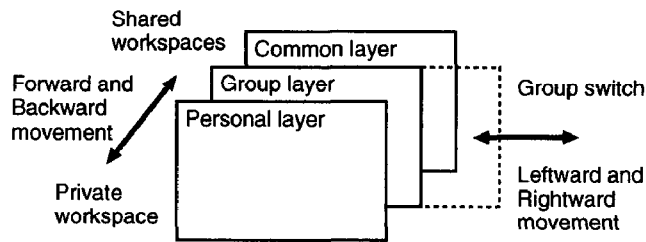


Figure 6: Switching workspaces with three-dimensional moving operations.

IMPLEMENTATION OF THE PROTOTYPE

In order to examine the availability of the layered workspace visualization in pseudo-three-dimensional graphics illustrated above, we have developed the system based on this conception. This section describes the implementation of the software with several screen images.

Overview of the System

Figure 7 shows an example of how the system is used. In this example, there are two layers of shared spaces, workspaces for a group and for all groups, behind the layer of the personal space. The personal space exists on top of the screen and transparently occupies the entire screen, and the shared workspaces are shown in perspective according to their sharing levels. Figure 4, mentioned earlier, illustrates also in which layer each window exists in Figure

7. In this example, an image processing software, a web browser and a calendar software are being launched respectively in the personal workspace (top front layer), the group workspace (middle layer), and the workspace shared by all groups (bottom layer).

Visualization Techniques

In Figure 7, the entire image represents a personal desktop screen and also an image of computer screen itself. In other words, the most front layer (personal workspace) is realized with conventional window systems of GUI. Group workspaces are shown as virtual root windows, or background wallpapers, of personal workspaces, that is, the system draws some another window systems in the virtual root windows repeatedly.

As well as in the top private layers, the system allows users to perform transparent windowing operation in background group layer. It is done by forwarding system events such as mouse operation to the virtual root windows. In addition, since windows in group workspaces are shared objects of all users who belong to corresponding groups, any user connected via network can also perform windowing operation such as opening and moving.

In this implementation, group workspaces are drawn 7/8 smaller and 7/8 or 3/4 darker than personal workspaces, by processing image of virtual screens in memories. Similarly, common workspaces are drawn, as well, 7/8 smaller and 7/8 or 3/4 darker than group workspaces. These visual effects enable users to comprehend in which workspace each window is shown.

Although recursive layering of workspaces more than three levels are even possible in the implementation, such excessive visualization is probably little meaningful for ordinary users. As described below, this system provides the feature of default workspace with the UNIX file permission. This is another reason why we adopt the three-leveled workspace.

Viewing Background Information

We have also developed the device that displays windows only with their frameworks for users to view and operate other windows hidden under them. Occasionally users need to refer to documents in group workspaces, which are often hidden behind the personal windows. In this case, users can change obstacle windows to framework shapes to manipulate objects hidden under the windows (Figure 8).

Because this feature makes windows only frameworks truly, users can directly manipulate information objects that appear inside the "holes" of the frameworks. Moreover, the title bars and the resize handles of the framework windows still remain, so windowing operations are still possible for users. We think that this feature is more useful than iconification to refer background workspaces temporarily.

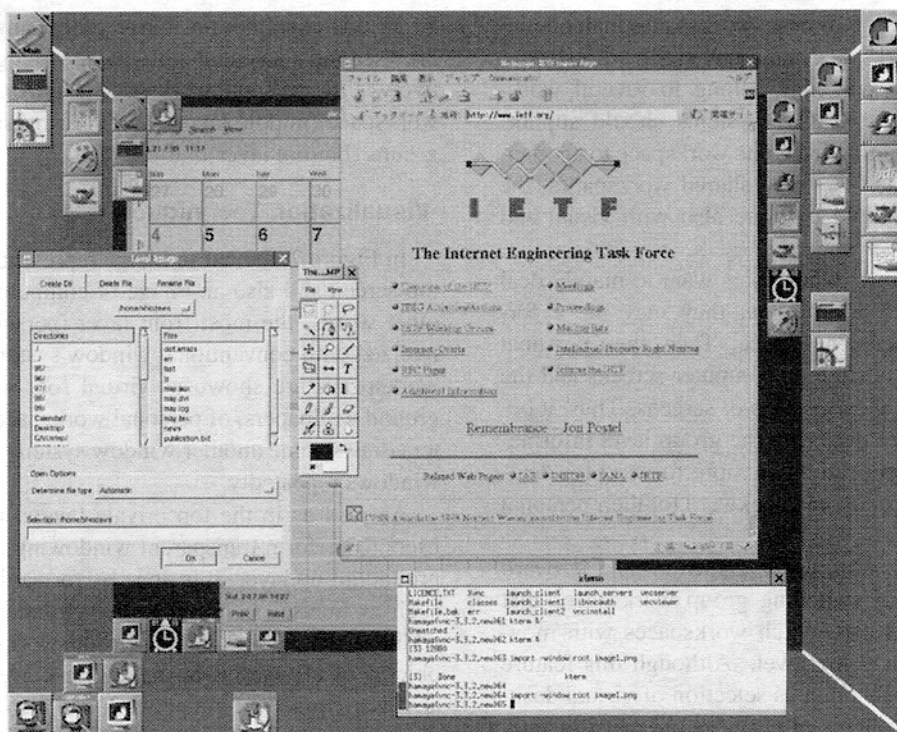


Figure 7: Overview of the prototype system.

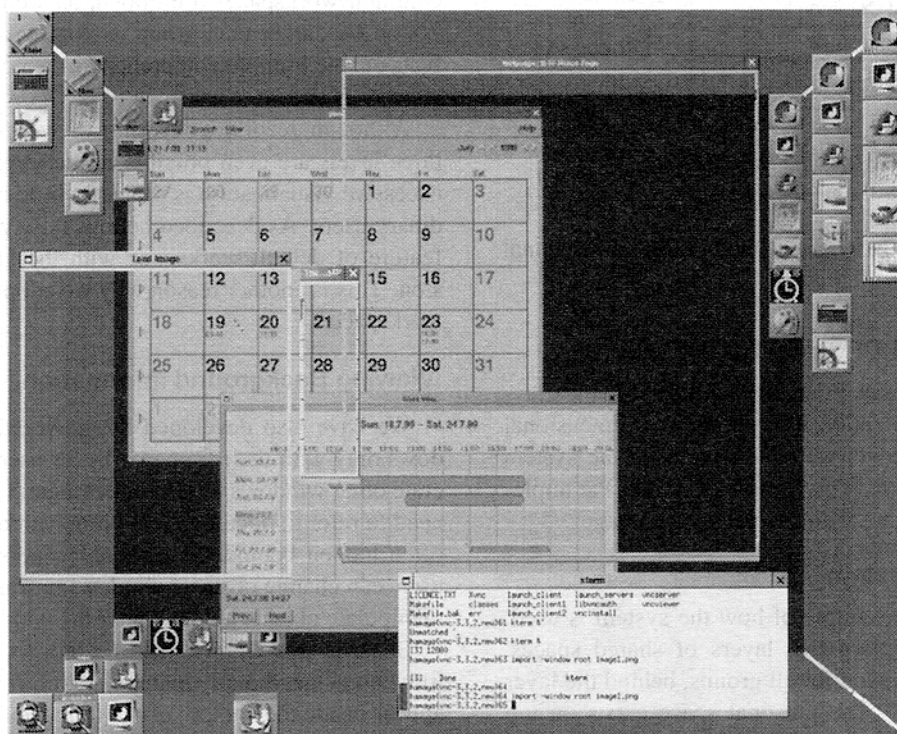


Figure 8: Framework windows for referring deeper layers.

Furthermore, the system supports awareness by showing shared workspaces instead of screen savers. Users can see shared information hidden under their personal windows, if they have not manipulated any objects for ten minutes (this term is configurable).

Inter- and Cross-Layer Manipulations

For intuitive and continuous switching of workspaces, the system provides three-dimensional moving operations that have mentioned already. Users can visually change workspaces with the three-dimensional moving operations with visual feedback.

If a user wants to go forward one deeper layer such as from the personal space to a group workspace, the user may move the mouse pointer to the top edge of the screen and click the button. Then the one level deeper layer become shown in the full screen instead of the current workspace (Figure 9). Similarly, if a user wants to go backward to personal workspace, the user may click the bottom edge of the screen.

Furthermore, if a user has more personal workspaces than one or belongs to more groups than one, the user may click the right edge or the left edge of the screen, to move between the workgroups of the same level.

Users can also transfer images of individual windows among workspaces; for example, they can put copied images of windows in their private workspace onto group and public workspaces. The window images are updated with synchronizing the original windows, yet users cannot edit or manipulate them, because copied windows are images. By this feature, the system provides a way for users to bring out their private windows for others, and to put copies of public information on their personal spaces.

Default Workspaces for UNIX Files

We have implemented a command line program that opens a document according to its default workspace. Although realizing this feature requires support of operating systems or databases, we utilize UNIX's SUID/SGID bits in this prototype. In UNIX, each file has these two bits in its permission, which are not utilized for ordinary files.

We utilize the two bits to indicate a default workspace of a document file, though these are related with security, so using these bits other than original purpose is not recommended for pragmatic environments.

If the SUID bit is set, the document is opened in the personal workspace, otherwise if the SGID bit is set, it is opened in the group workspace. If neither, it is opened in public workspace. The executable program that opens the file is determined by its extension (suffix) such as doc, html, and gif. Moreover, the program checks read permission of the file. Even if its SGID bit is set, it is not opened in the

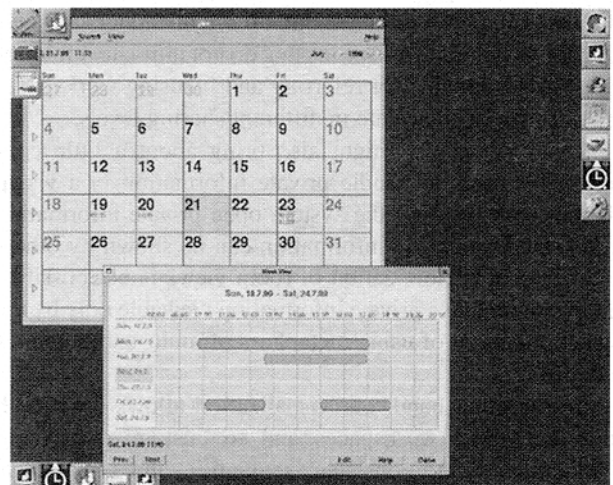
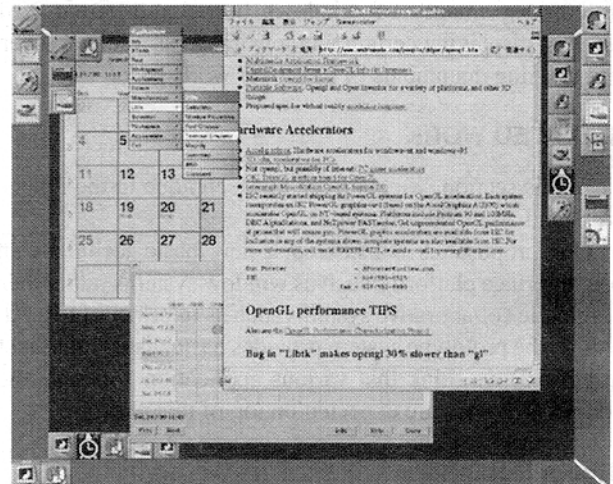
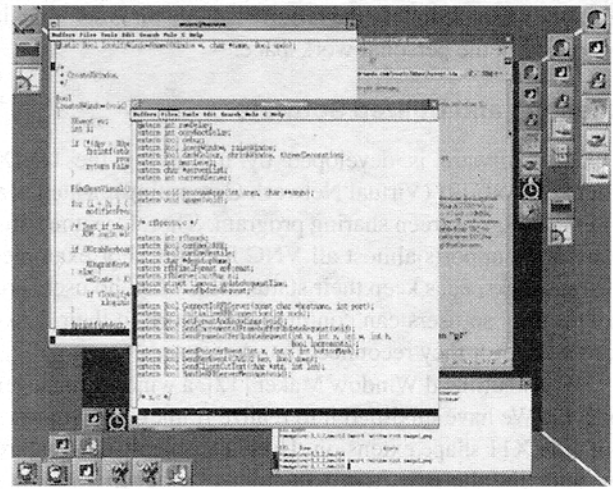


Figure 9: Forward movement for mainly operating in shared workspaces.

group workspace unless the group readable bit is set, then it is opened in the personal workspace.

Platform and Utilized Software

This software is developed by modifying the UNIX client of VNC [2] (Virtual Network Computing), which is a multi-platform screen sharing program. Therefore, the software also supports almost all VNC features. For example, shared workspaces keep their status even when no users are connecting, so users can continue their work in their desktops whenever they reconnect the workspaces.

We also utilized Window Maker [12], a window manager of X11. We have modified it to realize framework windows with the X11 shape extension. Users can enable this feature by selecting the new item "Skeltonize" in each window's title menu.

In addition, we implemented individual programs such as copying images of windows between different X11 screens, displaying certain window image as a screen saver, and opening documents in its proper workspace.

RELATED WORK

In this section, we compare our technique to the related work and argue their features.

Our proposal is considered a new basic technique of user interface platforms such as window systems rather than pragmatic collaborative systems such as Interlocus [16]. Although the prototype system provides basic visual interfaces at present, we think that various application software and add-on programs are expected on top of this platform.

Room Metaphors

Many groupware support room metaphors to manage multiple workspaces, for example, Rooms [9], Team-Rooms [17], DIVA [23]. We think room metaphors are suitable for switching workspaces that do not intimately interrelate, but not suitable for referring and focusing workspaces that intimately interrelate in different sharing levels.

Room metaphors might also bring about a little confusion for users to handle private information in a visual shared workspace. If the system open private information in a shared room, the information can be shown by others and personal customization of room views is not possible. If the system make private information viewable only by the owner, the merit of using metaphors of multi-user rooms is reduced.

On the other hand, our visualization allows users both to refer shared workspaces and to customize personal workspaces in the consistent semantics, and also allows users to be aware of sharing levels of work. Furthermore, our technique provides the feature to switch among group workspaces with horizontal movement in three-dimensional

space. So, similar interfaces to room metaphors can be implemented by this feature.

Shared Window Systems

Many software, such as XTV [1], XMX [3], VNC [2], have been developed to share application windows and desktop screens in existing window systems such as X Window System. However, these software have problems described in Section 2. Our technique features intelligibly indication of sharing levels of information and utilization of the desktop background. It enables co-existence of personal desktops and shared desktops, and also enables support of users' awareness.

Although current version of XMX shows a shared desktop as a virtual root window, this feature is not intended to support cooperative work and everyday awareness. Moreover, XMX shows a shared desktop without any image processing, so all windows have the same appearance and users can feel operational confusion. Indeed, if a user clicks a title bar of a random window, it may be popped up or may never be popped up. Which result is produced is hardly known before clicking. In contrast, our visualization makes users understand sharing levels of windows by visual effects.

Furthermore, Microsoft's Active Desktop technology allows users to paste or hang arbitrary web documents on the background. However, it is hardly used as a workspace with editing capability. We think that information on the Web is not intimately relevant with ordinary users and not updated frequently. On the other hand, groups' shared information are quite intimately relevant with the members and often updated very frequently. Thus learning modification of shared workspaces through awareness is more useful than random web documents in the Internet.

Graphical and Visual Effects

The three-dimensional perspective projection applied to GUI was mentioned by Staples [24] and implemented in MaW3 [13] and Web Forager [7]. We have proposed to utilize that for collaborative workspaces of CSCW. Furthermore, the presto-three-dimensional effect by layering two-dimensional displays is more intelligible to show sharing levels of hierarchical information, yet less flexible than the truly three-dimensional display.

Although three-dimensional interface have pointed out several problems such as users' disorientation and overwrapping of objects [22], our visualization offers the clear meaning to the third dimension to ameliorate them. We think that offering a proper meaning to each spatial direction keep users from operational disorientation and confusion [18, 19, 21]. We have also proposed the new inter- and cross-layer manipulations such as copying according to the meaning.

Overlaying multiple information can be realized also by transparency or translucence, and it was already applied to CSCW systems [11, 4]. These techniques probably can be used with our visualization. However, transparency causes visual confusion when the system overlays three or more information layers. On the other hand, perspective and darkness can more clearly tell hierarchical levels of information and prevent operational confusion of users.

FEEDBACK

This system is a prototype and able to work on only UNIX systems in certain settings such as full-color display. So, it is still difficult to evaluate the system in the real working environments that consist of various kinds of hardware and software, such as notebook-size computers running Windows and 256-color UNIX workstations.

We thus set up three machine as evaluation systems, and could be answered about the following questionnaire by eleven users. They used the system at least 10 minutes and asked the questions by rating on a five-point scale from 5 for "I think so" to 1 for "I don't think so". Figure 10 shows the result of the questionnaire. Note that question 9 is asked about the feature not yet implemented.

1. Did you think that it was useful to always show desktops being shared with co-workers?
2. If installing this software in your computer, do you think that you will be aware of changes in the shared desktops on the background?
3. Did you easily find that the middle layer windows were on deeper places than top layer windows?
4. Did you easily find that the bottom layer windows were on deeper places than middle layer windows?
5. Did you think that it was an appropriate operation to click the top edge or the bottom edge of the screen to switch the desktops as forward or backward movements in three dimension?
6. Did you think that this system was more easy to operate than virtual desktop systems to switch several workspaces?
7. Did you think that it was useful to show the background workspace like a screen saver in idle?
8. How many layers are enough do you think?
9. Do you think that it will be useful to show live video or similar images always on the background?

FUTURE WORK

This system provides a basic information sharing mechanism and a visualization platform of workspaces. We plan not only improvement of the system itself but also porting

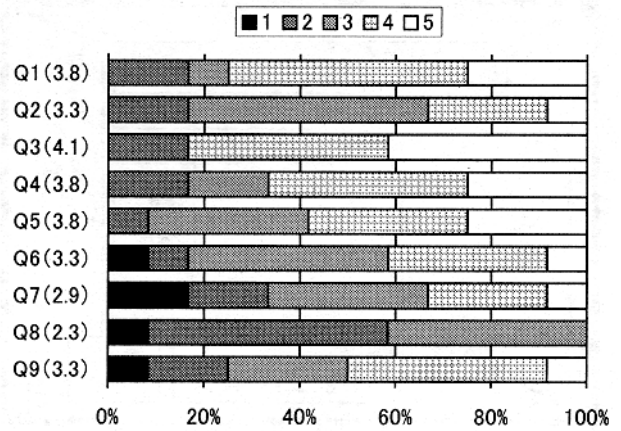


Figure 10: The questionnaire data (numbers in the parentheses are the average points).

to other operating systems and various applications on the system.

We are continuously improving the software performance, because the loads of image processing to make the perspective visual effect and screen image transfer on networks cause sometimes uncomfortable behaviors. And, we think that it is needed that simpler and more intelligible operations to movement in three-dimensional workspaces, to select and launch application software, and various interactive operations.

We have some ideas of applications of this visualization and are implementing them. For example, Figure 11 is a design of integration of portholes and who-where list. In this idea, each user has his/her window on the group layer to open their awareness information in his/her preferred way, while the system shows all groups' workers who-where information on the common layer. We think that the system will provide various levels of awareness like NYNEX Portholes [14] in more flexible and configurable approach.

CONCLUSION

This paper has described a new visualization technique that copes with the problems of visual shared workspaces on conventional synchronous groupware. The visualization shows shared workspaces as layered screens of window systems in perspective three-dimensional graphics.

In the near future, shared workspaces will be always staying on users' computer screen, and users will be working in their private spaces for personal and asynchronous work, while working in shared spaces for communication and synchronous cooperation. The visualization allows users to frequently move among several workspaces that they belong to.

There have been few researches on visualization of shared workspaces suitable for such new situation and re-

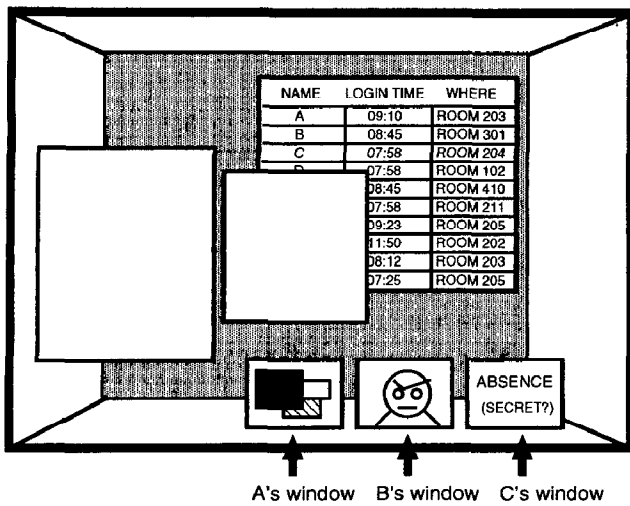


Figure 11: Design of portholes / who-where list.

quirements. In this paper, we have clarified the situation and usage of shared workspaces, and introduced the conception of the layered architecture, then described implementation of the new visualization of shared workspaces.

The system constructs visualization like as looking from a top personal layer down to a bottom public layer. In this visualization, personal application software, which are most frequently used, are shown in front position on the screen, while software supporting group information are shown in background of the personal ones.

The visualization is also suitable for transmitting various everyday awareness information. It applies the conception of information visualization to support users' awareness, and can show shared information and their modification always in the background. Therefore, the visualization has potential to be the user interface of integrated groupware platforms.

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