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A 3D Graphical User Interface Operable by Force Feedback Device

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Abstract: Although many 3D desktop environments have been proposed and implemented, they don't become a principal interaction method in human computer interface (HCI) research field. Difficulties in controlling 3D operations with mouse devices such as appropriately designating object's positions and directions in a 3D task space are major obstacles. In this paper, we propose to utilize a haptic device as an interaction device enabling easy object manipulations in the 3D task space. The haptic device also allows users to touch the objects with varied tactile sensations like vibrations, weights, and surface textures when they touch the objects. We designed and developed a 3D desktop interface allowing the users to efficiently perform many tasks in the 3D space. We describe the basic concept, operational interface, and enhanced functions of the proposed 3D desktop environment and elaborate how the haptic device can contribute for providing a natural and efficient operational environment.

1. Introduction

A variety of 3D desktop environments have been proposed and implemented in recent years. A traditional 2D desktop environment with many open windows as shown in Figure 1 requires users to waste their time for finding a target window because of many overlaps between them. It significantly decreases the efficiency of GUI operations. The 3D desktop produces a more realistic operational environment by converting a 2D planar work space to a 3D spatial task space. Figure 2 shows a snapshot of the 3D desktop environment designed and implemented in this study. It allows the users to neatly place the windows in three dimensions and easily select a target object.

Although it can improve the work efficiency, the research on the 3D desktop has not been progressed so far. A reason is the constraint of mouse operations. Most previously proposed 3D desktop environments in the HCI (human computer interface) research field visually implement their 3D task spaces, but they mainly use planar operational spaces with mouse devices. Users cannot proficiently execute the operations in a depth direction because of the mismatch between the input part (2D mouse operation) and the 3D output part (3D graphics drawing). Therefore, the users feel a sense of discomfort in controlling the 3D desktop operations with the 2D input device and they sometimes call such situation as the 2.5D desktop. Therefore, implementing a practical 3D desktop environment usable via natural and intuitive GUI operations is an important research goal in the HCI research field.

To resolve the above mentioned problems, we designed and developed the 3D desktop system as shown in Figure 2. The system visually presents the task space in 3D and allows the users to easily perform various 3D operations. It also presents tactile sensations when they touch the icons displayed in the task space. As shown in Figure 3, we utilize a force feedback device called FALCON developed and marketed by Novint Technologies, Inc [1]. It enables the users to easily carry out spatial operations that are hard to manage by using the mouse devices. The users hold the grip part and freely control a pointing position by moving it back and forth and around. There are four buttons in the grip as shown in Figure 3 and the users can click on the buttons to execute additional functions. When the users manipulate the icons, the system presents tactile sensations such as the weight and stiffness of the currently manipulating icon in the 3D task space. The users can efficiently perform the operations with the 3D visual and tactile presentations. We introduced a haptic computing engine called Haptx library developed and marketed by a Swedish company called Reachin Technologies, Inc. It enables developers to add various tactile effects on 3D graphics objects such as impactive force, gravitational force, and attraction force of magnet [2].

In this paper, we propose a new 3D desktop environment empowered by the FALCON force feedback device. In addition to the natural 3D input and output function, the system supports a more realistic interaction environment by taking advantage of the haptic device. It presents the sensation of touch for various icons displayed on a screen. In the following sections, we describe related work, the proposed 3D desktop system, experiments and improvements, and discussions about our future research.

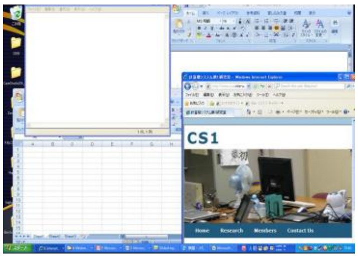

Figure 1. Standard 2D planer desktop screen in MS Windows.

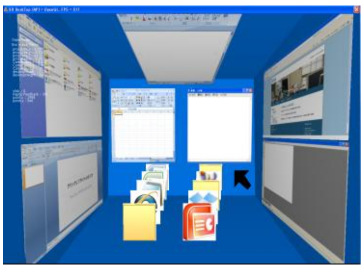

Figure 2. Proposed 3D desktop environment.

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Figure 3. FALCON force feedback device.

2. Related Works

Bump Top proposed by Agarawala et al. implemented a 3D desktop environment enabling GUI operations in a boxy virtual task space [3]. It could present some special effects such as collisions between the objects by simulating their weights and inertial force. Looking Glass supports functions for resting windows against both sides of a screen and translucently drawing inactive windows [4]. Task Gallery proposed by Robertson et al. implemented a common window manager with 3D metaphor [5]. The traditional 2D desktop applications can be managed in a 3D task space without any modifications.

These desktop environments basically use a mouse as a standard manipulation device. Because users need to manipulate objects on a 2D surface, it is difficult to efficiently manipulate them. In the real world, the users put various tools and documents on a desktop and pick up necessary objects for manipulations at different times. If they need to pick up an object set far back on the desktop, they need to find and grab the target one by unblocking other objects. The mouse is inefficient for executing such operations in the depth direction and brings discomfort to the users in such 3D manipulation tasks. As the mouse has become a primary device with the popularization of 2D desktop, so a new device and its usage is required for the wide spread use of the 3D desktop environments.

The above mentioned systems support very different functional specifications such as implementing operations with or without physical simulations, and allowing manipulations during movements or not. The current 2D desktop interface, on the other hand, is well standardized and provides similar manipulation methods for many years. Standardizing the interface, therefore, is an important requirement for task efficiency improvements.

3. 3D Desktop Operation Environment with Force Feedback

In this section, we describe the functions and operation environment of the proposed 3D desktop system. Figure 4 shows the initial screen of the system displayed right after the system start-up. As shown in Figure 5, the user can switch the icon layouts between 3D and 2D modes by pushing the TAB key. The system renders the walls and icons by mapping the color (ASE) and image (BMP) data on plate-like 3D polygons.

The haptic cursor as shown in Figure 4 indicates the current position in the 3D task space. When the user holds the FALCON's grip part and moves it back and forth and around in the task space, the cursor moves in synchronization with the user's hand movements.

When the cursor collides with the walls, icons, or windows, the system changes its color from black to red and then calculates and presents a reaction force through the FALCON device. When the user moves the cursor close to a specific icon, the cursor is pulled toward the icon. This function helps the user to easily select a specific icon located in the 3D space. Because the user feels an attractive force to the icon through the FALCON device in the selection operation, he/she can manipulate the object with a good sense of reality by feeling the tactile sensation in addition to the visual information. Drag and drop operation can easily be performed in a similar fashion. The user can move the windows and icons by superimposing the cursor on the target object and dragging it by pressing the centre button on the FALCON grip. When he/she releases the button, the grabbed object is placed on the current cursor position in the 3D task space. If the user pushes an object with his/her force, the application programs associated with the object will be launched.

When an application is running in the task space, a pair of windows, a real running application window and its virtual counterpart, are appeared. Figure 6 shows the screen captured when the Windows memo pad application is launched. The window marked as A is the virtual window displayed in the desktop space and is used for 3D manipulations with the FALCON device. The user selects the real window marked as B in the figure for typing texts. The user activates the desktop space for various 3D operations and selects and pushes the virtual window for returning to the real window of the running application. Therefore, he/she needs to switch operation modes between the 3D desktop and the Windows desktop environment.

As shown in Figure 7, the system displays the normal cursor used in the Windows desktop when the user selects the real window. Because the system allows the user to control the normal cursor by using the FALCON device, he/she doesn't need to use a mouse. The buttons on the FALCON grip shown in Figure 3 provide the same functions with the mouse buttons.

Launching multiple applications increases the number of displayed virtual windows and makes the task space a cluttered state. The system enables the user to efficiently rearrange the windows' layout. In Figure 2, six virtual windows are rested on the side walls and one on the ceiling in the 3D space. These rearrangements are possible by simply moving each window toward a target wall surface. As shown in Figure 8, if the user moves a window toward a side wall, the window gradually turns around and finally leans over on the wall or on the ceiling. Each window can be scaled by using the left (shrinking) and right (magnifying) buttons on the FALCON grip.

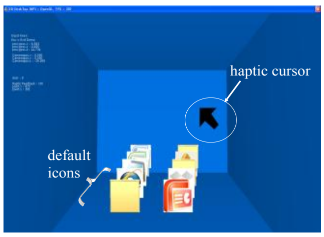

Figure 4. Initial screen displayed right after system start up.

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(a) 3D layout (b) 2D layout

Figure 5. Two types of icon layout.

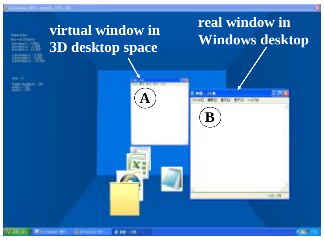
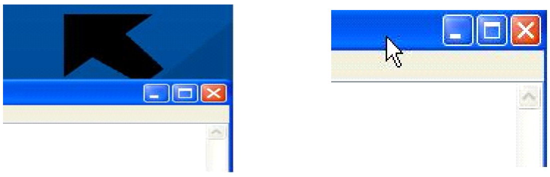


Figure 6. A pair of windows appeared when the Windows memo pad application is launched.



(a) Haptic cursor used in 3D desktop environment (b) Normal cursor used in Windows desktop

Figure 7. Two types of cursors used in 3D and Windows desktop environment.

(a) (b) (c) (d) (e)

Figure 8. Arrangements of virtual window layout in 3D space, resting it to the side wall (a-c) and to the ceiling (d-e).

4. Experiments and Improvements

4.1 Initial experiments

We have conducted two experiments for verifying the effectiveness of the proposed system [6]. First experiment was conducted for investigating whether the existence of haptic modality has an effect on the operability of the 3D desktop environment. Second experiment was performed to see if the haptic modality works for improving the operational performance of 3D spatial interactions.

As a result in the first experiment, more than 60% subjects indicated the operability of 3D spatial manipulations was improved by haptic modality. But they also pointed out a problem that force feedback induced fatigue.

Though we cannot judge the effectiveness of the system statistically, the experimental results showed the haptic device is good for both input (performing 3D manipulations) and output (presenting realistic feeling of 3D object) parts in the proposed 3D desktop environment.

Although the experiments showed our approach is relevant for enhancing the operability, improving the work efficiency should be considered to make the system a more practical one. Integrating the touch sensation to the basic operations commonly used in multiple applications such as shortcut key functions is effective for achieving better performance. Providing a way for effectively managing a more complex desktop environment with more icons and windows is another important issue in terms of usefulness. Thus, we are now focusing on the following points to enhance the system functionality and improve its practicality. The following new operation methods are designed and incorporated to enhance the system usability and user performance.

4.2 Design and implementation of gesture-based operations using haptic device

Shortcut key operations can be executed by gesture motions with the FALCON device. The shortcut key function such as a “copy and paste” operation is a convenient mean for efficient GUI manipulation, but it also is a troublesome task. When using a keyboard, a user tends to press the wrong key by mistake due to the difference of key layouts. If the user wants to copy (Ctrl+C keys) and paste (Ctrl+V keys) texts, images, and files, he/she grasps the FALCON grip, pulls it from the source for copying, and pushes it to the destination for pasting. These gesture operations are designed based on the real-world tasks such as a user picks up a favorite photo and puts it in a photo album. When the user executes the gesture operation, a tactile feedback such as a reaction force is simultaneously presented. It wakes the user to recognize what he/she carried out by using the shortcut function through the tactile sensation. We devise such new operations based on the intuitiveness for using the haptic device to improve the user’s work efficiency.

If the user presses the top button in the FALCON grip, the cursor is trapped in the shortcut box as shown in Figure 9. The user can execute the shortcut key function by manipulating the cursor and touching the specific box surface indicating his/her desired operation. When the cursor collides with a surface, the system presents a reaction force acting perpendicular to the surface. As shown in Figure 10, different shortcut key functions are assigned to different box surfaces and the type of assigned shortcut key function is changed depending on which window is in an active state. When the Internet Explorer window is in an active state, page back (Alt + left arrow) and page forth (Alt + right arrow) keys are assigned to left and right side surfaces, respectively. If the MS-Word window is activated, undo (Ctrl + Z) and redo (Ctrl + Y) keys are assigned to left and right side surfaces. This allows the user to execute various shortcut key functions in different applications by using identical gestures.

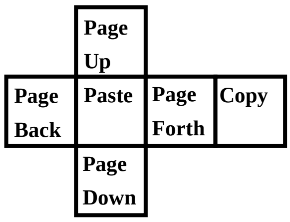


Figure 9. Shortcut box. Figure 10. Development view of shortcut box. (When Internet Explorer window is in an active state)

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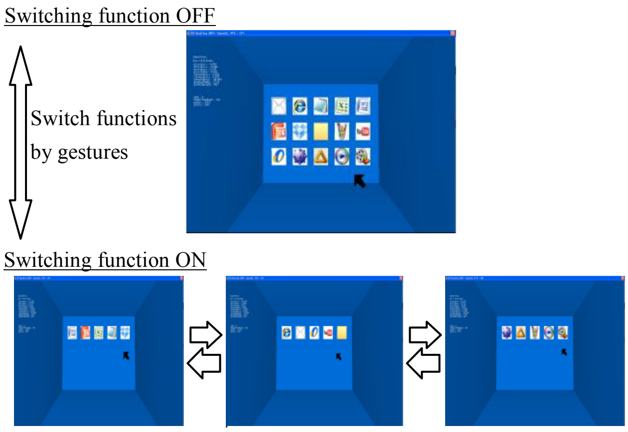
4.3 Design and implementation of desktop switching function

Although one display presents only one desktop generally, independent multiple desktop environments can be activated in one display by using the desktop switching function. The user can efficiently perform tasks by switching the desktop among them. There are, for example, virtual desktop software such as Linux Compiz [7] and Windows VirtuaWin [8]. These desktop software applications, however, only support the standard 2D desktop environment. Because reducing overlaps between running windows on a single desktop screen is difficult, we came up with an idea for implementing the desktop switching function in the 3D desktop environment to solve the problem. This method enables to diminish multiple running windows to overlap in every desktop environment and perform intuitive desktop operations with tactile feedback.

Figure 11 shows the basic mechanism of desktop switching function. When the 3D desktop system is activated, the function selector is assigned to the front surface in the shortcut box. When the user pushes the FALCON device to activate the desktop switching function, one desktop is divided into three desktops. Each divided desktop aggregates a group of icons related to a particular task as shown in Figure 11 (a), (b) and (c). The user can perform each task more efficiently by selecting the appropriate desktop, so the user needs to manipulate icons and windows required only for a specific task. Additionally, he/she can switch the desktop with FALCON gesture operations (move left and right) to immediately switch the task space. We are developing the desktop switching function for controlling multiple applications with predefined three task spaces. Allowing the user to customize the definition of the desktop structure to suit his/her task contents is a future extension.



(a) for reading and writing documents (b) for exploring Internet pages (c) for entertaining activities

Figure 11. Basic mechanism of desktop switching function

4.4 Information presentation through the tactile sensation

Human can get some specific information they can't look and hear through touch sensation. For example, the touch sensation can describe the approximate size or numbers of files included in multiple folders by presenting some haptic properties like vibrations and weights. In the development of haptic interface, thorough considerations on "which effect" should be used for presenting "what information" is an important issue. Therefore, developing application scenarios to appeal the potential ability of haptic modality is a crucial task in our future work.

Although the system improvements proposed in this section still is in a prototype stage, we would like to evaluate the efficiency of the above mentioned functions and make the system a more practical and novel desktop interface.

5. Conclusions and Future Works

We proposed an enhanced 3D desktop environment for solving problems found in some previously proposed 3D desktop systems. We adopted a haptic device, the FLACON force feedback device, as a single unified operation device. The proposed system implemented a realistic desktop space by visually presenting the space with 3D computer graphics. It also gives the users an additional modality, a sense of touch, through the haptic device. We conducted experiments to validate the effectiveness of the proposed system and found the promising results. Based on the experimental results, we further designed and implemented some functions to improve the system usability and user performance by the aid of haptic sensation.

As a future issue, we would like to conduct an extensive evaluation with larger number of subjects to verify the effectiveness of the enhanced functions proposed in this paper. Deeper analysis of 3D tasks performed in the proposed system is another crucial issue to make more realistic and natural 3D desktop interface [9].

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