HybridDesk : A Low Cost Semi-Immersive System for 2D-3D Interactions

Abstract

The HybridDesk is an immersive compact solution for visualization and interaction using low cost products. Screens were organized in an small set where a user can interact in a virtual environment sat in front of a desk, and even a standard mouse, keyboard and monitor can be used . Different from a regular CAVE the head is tracked outside the display cube and with the support of a wiimote the interaction can be controlled with a good precision. Several tests were conducted until the best and cheapest combination of technologies was achieved. Home projectors and mirrors were used using a semi-automatic calibration and finally a simple video splitter was used to produce the video source for the four projectors installed.

Index Terms: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality; I.3.2 [Computer Graphics]: Graphics Systems—Distributed/networks graphics

1 Introduction

Several new areas of applications that can take advantage of immersive environments emerged, like animation, CAD (Computer Aided Design), interactive 3D visualization, entertainment and games. The inherent characteristics of these classes of applications have created a demand which was not fully met by the desktop metaphor as it was originally proposed to represent an office desktop through WIMP (Windows, Icons, Menus, Pointer) interfaces. These points conduct us to develop a new computer user desk, not limited to a single display but a configuration where the user can be semi-immersed in a computer desktop.

Applications such as CAD, 2D image editing and graphics applications involving two-dimensional data are still compatible with the desktop metaphor, because they remain similar to tasks performed by engineers and architects using their boards in their respective offices. However, the emergence of three-dimensional interactive applications brought attention to the limitations of conventional 2D desktop devices (mouse, keyboard and monitor). Such a conventional setup does not meet all the interaction needs related to the additional dimension in this new environment. The main evidence supporting this fact is the existence of a research line focused exclusively on 3DUIs (3D User Interfaces). The early efforts were guided by the evolution of scientific visualization and flight simulator applications driving the development of a new set of interactive hardware, such as head mounted displays (HMD), data gloves and CAVES [5].

For a long time the 3DUIs were developed in parallel with WIMP interfaces and their contributions were added gradually to desktop computers as demanded by the 3D applications. Despite the high costs of the first 3D devices, the access to these technologies is increasing by means of new low cost devices. Evidence of that can be found in the use of devices such as stereoscopic glasses and gloves in 3D games and in scientific visualization applications. In the Wii game console, for example, there is a device called Wiimote that incorporates research results on the development of 3D tracking devices. Several 3D interactive techniques were also developed using mouse- and keyboard-oriented desktop, and the success of these efforts is evident in computer games.

This gradual convergence of interfaces from different natures (such as WIMP and 3DUIs) resulted in the emergence of other interfaces that share characteristics of both. The wide variety of hardware and software, and the different interaction techniques proposed are potential “ingredients” for a research field called Hybrid User Interfaces (HUI) [8]. In this field, efforts are being joined in order to blend harmoniously both virtual (applications, interaction techniques, graphics, etc.) and physical (the input and output) elements from one or more interfaces. In this way, the design of HUIs may result in new interfaces with hybrid resources which were inspired by other interfaces with the goal of integrating previously separated functions. Such mixture of elements is not an easy task, taking into account the cost of some technologies, mainly those related to 3DUIs, like for example, high resolution projectors, stereoscopic systems, trackers and clusters of workstations. In order to handle this issue, a careful choice of low cost equipments must be done to achieve reasonable results.

The purpose of this work is to present the details of the development of a workspace called HybridDesk, featuring a mix of different devices to allow the use of three interactive environments for performing tasks with different hardware requirements. This workplace attempted to use semi-immersive visualization using low cost equipments instead of expensive commercial solutions.

The remainder of the paper is structured as follows. Section 2 reviews relevant work in the areas of Hybrid User Interface. The HybridDesk prototype is introduced in Section 3. A trade off discussion about low cost and semi-immersive equipments is presented in section 4. Finally, Section 5 presents conclusions and discusses future directions of this work.

2 Related Works

Several Interface systems that attempt to combine hardware and software components are called Hybrid User Interfaces (HUI), Mixed Reality Systems or Hybrid Display Systems. The following research projects are characterized by the use of multiple elements.

A pioneer work in this area was the Office of the Future [14], which combined several computer vision and computer graphics techniques to analyze surfaces of the real world and then add virtual information projected on them. Rekimoto [16] explored the HUI heterogeneity using several computers and displays (projections and notebooks) in the same work environment.

Nakashima [10] presented a prototype of a collaborative work environment with 2D and 3D environments for graphics modeling tasks. The environment uses a display called IllusionHole for 3D interactions, while 2D interactions are supported by a projection. An HUI for the manipulation of medical data also using 2D and 3D interactions was developed by Bornik [3]. In this HUI, a single 3D pointer is used as interaction tool and two visualization forms are available, one on a tablet and another on a projection.

Benko [2] created a hybrid environment composed of an LCD display placed vertically, a touchable display placed horizontally, and a see-through HMD for AR. This environment is used for the manipulation of archaeological objects. Baumgartner [1] presented an HUI to explore the organization of a desktop, disposing documents spatially. The organization of documents is made through gestures, using a glove. The documents in the 3D space are visualized in an autostereoscopic display and edited using the keyboard and a pen on a tablet below the display.

Geiger [9] proposed extensions of a commercial 3D authoring system to create a visual framework dedicated to the prototyping of HUI. Preliminary evaluation in an L-shaped table-top display featuring 2D and 3D GUI indicated that the proposed framework was adequate for rapid prototyping of multimodal and hybrid user interfaces.

In general, the works mentioned above sought to blend different technologies in order to execute certain tasks. Some of the implementations use expensive state of art devices, however, most of them do not concern about the use of low cost technologies, nor a reference to any methodology or concept driving this “technological mixture”. Moreover, there seems to be no explicit concern about possible transitions among the integrated technologies.

3 System Design

The design of the HybridDesk (Figure 1) was based on the requirements for a 3D annotation task. These requirements helped identify the hardware set used to compose the interaction environments within HybridDesk.

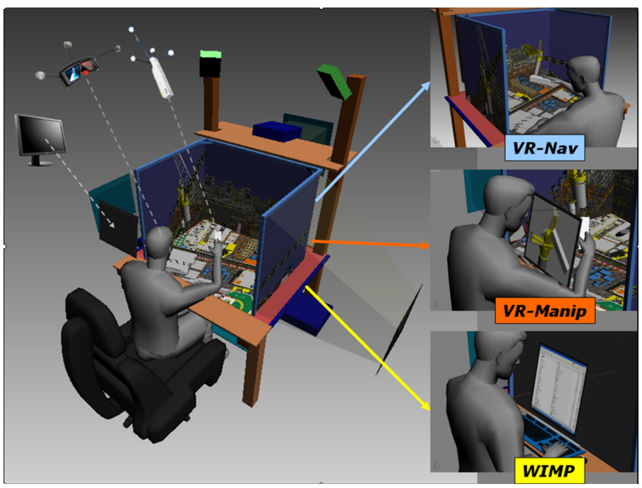

Figure 1: HybridDesk scheme with the interactive environments.

The annotation task is a way to insert textual information into a virtual environment (VE), and this information is often related to a particular object. Regarding 3D interaction aspects related to the 3D annotation task, the following subtasks were identified:

1) 3D Navigation and 3D Selection: to search and select an object or to explore the 3D virtual environment. For these subtasks, VR and some associated 3DUI techniques are appropriated interface paradigms.

2) 3D Manipulation: to manipulate objects through translations and rotations, and to enable the insertion of annotation using 3D Icons (the visual feedback of those icons has a shape of a 3D cube). VR is also a suitable interface paradigm for this subtask.

3) Symbolic Input: to create and edit textual annotations. To handle the creation and management of symbolic information we have chosen to take advantage of users’ experiences with WIMP interfaces rather than to create a completely new environment. The “3D shortcuts” (3D Icons) to these files are created inside the virtual environment, and linked to the annotation files created by the user in the WIMP interface.

In order to support the subtask requirements described above, we designed three interactive configurations for the HybridDesk: VR-Nav, VR-Manip and WIMP.

In order to physically merge these technological setups from the three environments, a structure was built in the form of a table composed of four screens driven by rear projectors and an additional LCD display (Figure 1). Two legs were extended to a height of two meters in order to include cameras for a tracking system. A extended piece of wood was set in front of the whole structure to provide support for devices such as mouse and keyboard in addition to support for the peoples arms.

Mechanisms of transition between environments were implemented aiming continuous transitions along the sub-tasks. The description and discussion of these issues were presented elsewhere *(removed due to blind review)*.

3.1 VR-Nav - Visual Immersion for Navigation and Selection

This sub-environment was used to perform a navigation task in an immersive 3D virtual environment. Some studies have indicated that navigation tasks tend to benefit from displays with larger FOV (Field of View) and FOR (Field of Regard) [6, 15, 18]. Because of the larger visual space of these displays, their properties also provide better support for searches during selection tasks [13, 17].

The hardware setup of VR-Nav is composed by the four projection screens that are used simultaneously to provide a broader FOV and a larger physical visualization area near the user. The display resulting from this set of screens was named “MiniCave” and was inspired by the idea of a CAVE [5] adapted to a desk.

A wand (a Wiimote tracked by an optical tracker) was used as input device, and a 3D representation for it was created in the VE. This representation was visually similar to the real device and receives the translations and rotations from the tracker device. Moreover, head tracking was provided through tracked glasses, and there is anaglyph stereo visualization.

The MiniCave screens were designed using pieces of glass for the three vertical screens and a piece of acrylic for the table top (Figure 2). Projection screens were placed inside the Minicave over the surfaces of the glasses and the acrylic.

Figure 2: VR Nav - 3D Navigation and Selection.

A set of mirrors was used to decrease the distance between each projector and the corresponding screens (Figure 3). Mirrors with frontal reflection (coating in the frontal surface) were selected in order to avoid double reflection. A wooden frames containing a mirror was constructed (Figure 3.a) enabling some control of position and orientation of the reflection. Some optical correction were also used on some projectors due to the projector's position and orientation adjustments, for instance, the inclination of the projector on Figure 3.c.

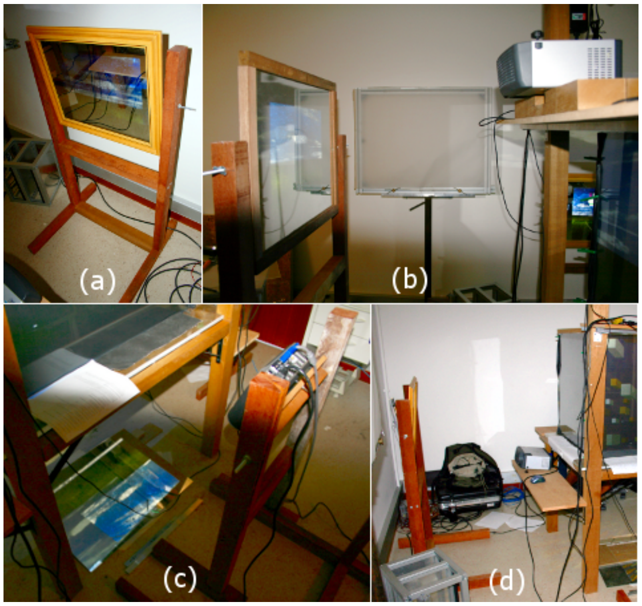

Figure 3: (a) Mirrors in MiniCave. Pair Projector/Mirror on screens: (b) frontal, (c) under the table and (d) sides.

3.2 VR-Manip - Manipulation

For manipulation tasks, we have understood that it is important to perform a detailed visual inspection of a selected object in order to identify particular points to leave annotations. We therefore chose an isomorphic interaction technique to handle virtual objects at a short distance, like people do with real objects. Local Manipulation (i.e. short distance) tasks have shown evidence of being more prone to visual stimuli in a restricted visualization area, because the attention is directed to a small visual space, which suggests the need for a narrower FOV [17, 7, 12]. However, as the focus of attention is more intense in this restricted area, visual cues are more noticeable. Thus, display features such as brightness, resolution, sharpness, and photorealism become important [11].

The inspiration for the technological setup came from the idea of a reachin display which allows the manipulation of virtual objects within the arm's reachable space. Most reachin displays use a mirror or a semi-transparent surface to show an illusion of a virtual content behind it. Such illusion is based on the reflection of an image from a CRT display or projection screen. For all these reasons a LCD display was chosen to help during the manipulation task. Although a regular LCD is much thicker than a mirror or glass, the results presented that the user has reasonable access to the space behind it (Figura 4.a), which is the area of interaction with the virtual objects selected on the VR-Nav. Moreover, a regular LCD has all required display features to facilitate the visual inspections. The LCD was fixed in a system of rails positioned horizontally at the desk, in front of the *MiniCave* (Figure 4.b). Also it allowed a mobility along the axis of the rails (Figura 4.c).

The same wand used in VR-Nav and its virtual representation were used as input device and visual feedback. Although the view of the real hands and the real wand are obstructed when the user puts them behind the LCD, the movements of their virtual representations provide a good reference for spatial awareness, and avoids problems of a precision and latency of tracking head and wand.

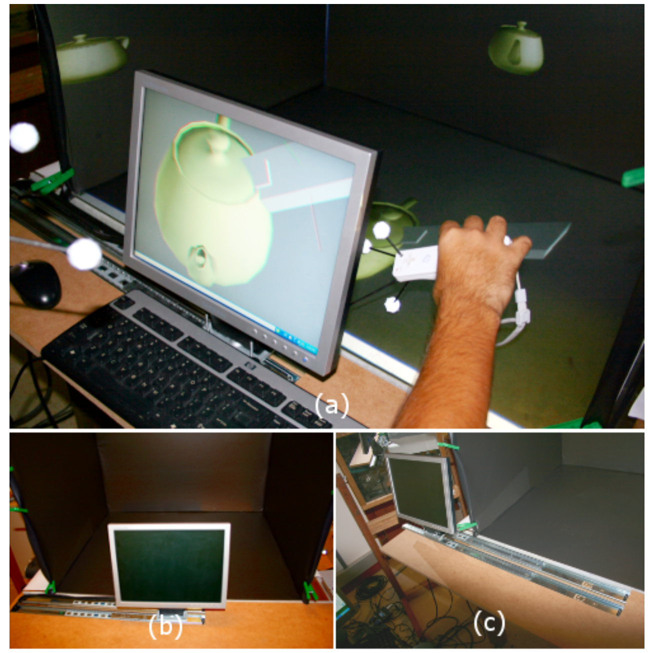

Figure 4: (a) VR Manip inspired on ***reachin displays***. (b) and (c) Rail system to enable LCD movement in front of the MiniCave.

3.3 WIMP

To use the resources of a conventional WIMP interface, a large enough desktop was created to fit the screens of the MiniCave and the LCD (main screen). Mouse and keyboard were placed in front of the MiniCave in a small shelf with enough space for them. The interactions with Microsoft Windows were made in the conventional way. The only addition was the insertion of a context menu in the file manager with two items that can start the transition to other environments.

4 Trade-offs

Instead of using a cluster of PCs and synchronization mechanisms, the semi-immersive visualization at the HybridDesk was managed by a single PC with a 3D accelerated video card with two video outputs. The HybridDesk needs a minimum of five video outputs: 4 to projectors and one to the LCD. In order to handle this configuration, two video splitters were used. These splitters are of the type *TripleHead2Go* and they split one video signal in three. Basically each splitter has a driver which increases the resolution of the desktop over a video output, and then the hardware splits it. For example an output with a resolution of 3078x768 pixels can be divided in three outputs of 1024x768. Thus, an extended desktop of 6 video output was created, three of 800x600 (2400x600) and the three of 1024x768 (3072x768). These outputs together formed a large desktop display over the projectors and the LCD.

The three-dimensional effect was achieved using the stereoscopic anaglyph technique in the projection screens. As the generation of stereoscopic image was all done via software, and only one resulting image was displayed for each screen, there was no need to use special screens neither the use of advanced projectors. Of course one of the disadvantages of the anaglyph is the color degradation of the final image, but the final results did not compromise the operation and most of the user do not complain about the anaglyph.

Using a wiimote as a wand was a reasonable choice, since it is cheap and offers a variety of events without the need for wires, since all data communication goes via bluetooth. Some retro-reflexive spheres were installed on the Wiimote for the optical-tracking system (the wiimote's camera was not used).

OpenSceneGraph library [4] was used to generate and manage 3D graphics. The system rendered and managed six virtual cameras: 4 for the MiniCave (Figures 5.a and 5.b), one for the LCD, and an extra camera for an overview of the position of the observer within the virtual environment (Figures 5.c and 6.h). In order to create the anaglyph stereoscopic images, 10 images per frame were computed to generate the left and right eyes for each virtual camera (the extra camera did not use stereoscopy).

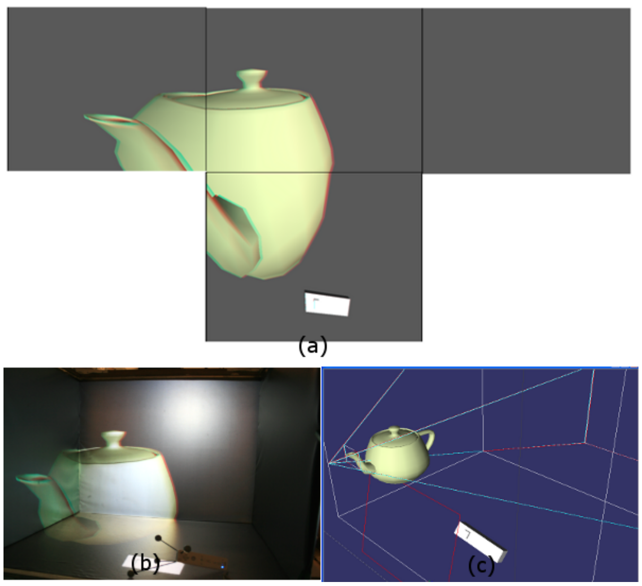

Figure 5: (a) and (b) showing the set of virtual cameras used in MiniCave. (c) Extra camera to provide an overview of the user position inside virtual world.

For each virtual camera, the system also created a window on the desktop so that each window occupied an area corresponding to a video output. In Figure 6 there is a screenshot showing the whole desktop and all the windows created for the HybridDesk. The edge of the images were mapped in a semi-automatic way, controling the borders of the images in a first step.

5 Conclusion

We have developed a semi-immersive environment consisting of three interactive environments through a combination of interaction devices comprising the tasks of editing text (2D), selection, navigation and manipulation (3D). The interactive environment of the task of editing texts follows the requirements of a WIMP interaction-based 2D mouse and keyboard. The interactive environment for navigation and selection tasks was designed in a CAVE adapted to a desk. Finally, the 3D manipulation task was accomplished through an interactive environment designed using an LCD as a reachin display to perform short distance manipulations.

The HybridDesk was assembled using simple components. Basically all the structure is made of wood, that is simple and not expensive. The wood is also very strong and all the projectors, cameras, screens and other devices can be installed in the structure. Although the screen resolutions were no so high, the higher distance between the user and the screen reduced this problem, and during the stereoscopic operations the resolution issue is not perceivable.

Although the design of HybridDesk has been influenced by the context of the 3D annotation task, other contexts applications can be used, for example, in medical applications where visual inspections are required on 3D volumetric data followed by the creation of reports using WIMP tools. Something similar can be noticed on the work of [3], where two displays were used, the first being a big projection with stereoscopy and the second being the a LCD.

The use of more accessible technologies is still a challenge to start more ambitious projects involving immersive virtual reality, thus the results from the HybridDesk development show that it is possible to find a balance in the use of current technologies (modern video splitters and wiimotes) with old technologies (anaglyph stereoscopy, projectors and conventional projection screens).

The use of a tracked mouse as a universal mouse-pointer to handle both 3D and 2D interaction will be investigated. Another possibility is to change the stereoscopy type by the use of new 3D home projectors due to their low price.

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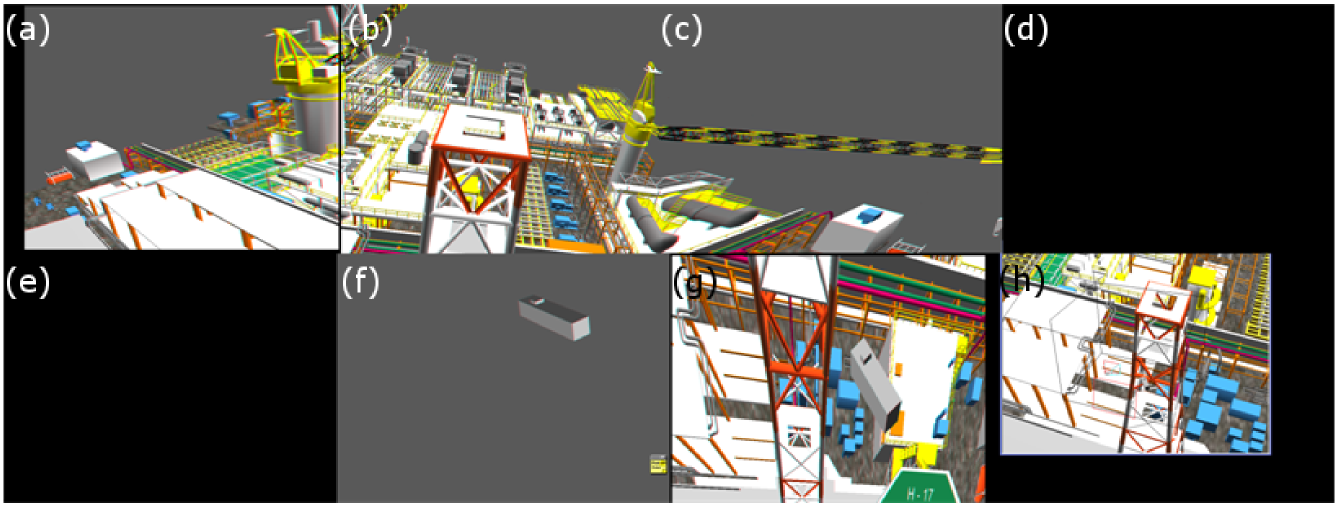

Figure 6: Screenshot of the extended desktop showing the 6 windows for the screens: (a) left, (b) front, (c) right, (f) LCD, (g) inferior, and (h) overview. In (d) and (e) are empty spaces generated by the splitter driver to compose a rectangular final image for the screenshot.

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