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AN APPROACH FOR ENABLING THE USE OF IMMERSIVE VIRTUAL REALITY IN DESKTOP HYBRID INTERFACES

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ABSTRACT
Hybrid User Interfaces, which create a heterogeneous environment providing different interaction forms and devices, may be enhanced by exploring more extensively the mixed reality continuum, which ranges from the real world to the complete virtual world, passing by augmented reality and augmented virtuality. Some hybrid interface approaches have been developed making use of the real world or enhanced by augmented reality resources. This work presents an alternative to include immersive virtual reality in hybrid user interfaces in a common desktop setup. In order to enable this inclusion, augmented virtuality was used to enhance the virtual environment with real world information. In this case, that information refers to the physical interaction space available in the users desktop. Some advantages of the use of immersive virtual reality in this context are discussed by means of the analysis of 3D interaction techniques.

KEY WORDS
Hybrid User Interfaces, Mixed Reality, Virtual Reality, 3D Interaction Techniques.

1. Introduction

The concept of Hybrid User Interfaces (HUI) was initially approached by Feiner [1], characterizing a heterogeneous environment, rich in terms of interaction techniques and composed of different types of devices, used in a complimentary and advantageous way. The concept of continuous interaction space became more evident in the context of HUI following the ideas of Ubiquitous Computing, which argues that interaction environments should not reside only in the user desktop, but also in other devices and in surrounding world. The work of Rekimoto [2] and the EMMIE project [3] are good representatives of those ideas.

Heterogeneity is another important characteristic of HUI and it has been explored in the context of the use of different types of computers in the same workplace. It would be interesting to explore this heterogeneity also in the context of giving more interaction environments in the same physical workplace. It is important to clarify here that we refer to workplace or work environment as the physical space where the user is located, i.e., the desktop setup. On the other hand, interaction environment is where the interaction techniques are executed, for example, virtual reality or augmented reality environments, or 2D typical WIMP (Windows, Icons, Menus and Pointing Device) GUIs.

One possibility, in the sense of providing more interaction environments in the same workplace, is to execute and experiment 3D interaction in a common desktop workplace. Recent studies have demonstrated that in certain situations a mix of 3D and 2D interaction is preferred over exclusive use of one or the other [4], [5]. The inclusion of Immersive Virtual Reality (IVR) together with an Augmented Reality (AR) and 2D GUI's in the same physical work environment would increase the alternatives of work practices in this hybrid environment. This kind of HUI is possible by the addition of other 3D interaction techniques, an immersive environment, a Head Mounted Display (HMD) with a webcam attached, and transitional interfaces.

In order to better understand our proposal, it is necessary to describe the mixed reality continuum and the concept of transitional interfaces. The mixed reality continuum was defined by Milgram [6] as a spectrum having the real world at one extreme and the virtual reality at the other. Along this spectrum, there are also the Augmented Reality and the Augmented Virtuality (AV). AR is based on the real world enhanced by virtual information, while AV is based on the virtual world enhanced by information of the real world.

In the MagicBook project [7], the concept of transitional interfaces was introduced, which are interfaces to move seamlessly along the mixed reality continuum. In an application that illustrates this concept, the user may be reading or observing the illustrations of a book enhanced by 3D graphics in an AR environment and may also be immersed in the virtual world of these illustrations.

In the MagicBook sample application, the AR to IVR transition isolates the users from the real world, which loose the real world surrounding visual perception. Therefore, care must be taken with the potential collisions with real objects that are close to the user. This kind of problem is treated in some IVR experiments, but with the goal to reduce possible breaks in presence, i.e., events that may deviate the users' attention from the virtual world to the real one [8]. In the context of this work, the major focus is not the break in presence, but the users' awareness about the limits of their physical interaction space, without impairing the interaction in the immersive virtual environment. In this work, we discuss that these limitations does not impede the use of many 3D interaction techniques.

In order to inform the users the limits of their physical interaction space, we propose the insertion of simple geometric descriptions of the potential collision parts of the objects of their desktop workplace (top of the table, front part of the displays, walls etc.). The real objects are tracked to supply their localization to the virtual world. The geometric representations of the real objects use transparency to reduce their impact on the visualization of the virtual world (for example, avoiding occluding the users' field of view). This work also explores variations in the use of transparency in the representation of real objects. Figure 1 illustrates a desktop setup and its representation in the IVR world.

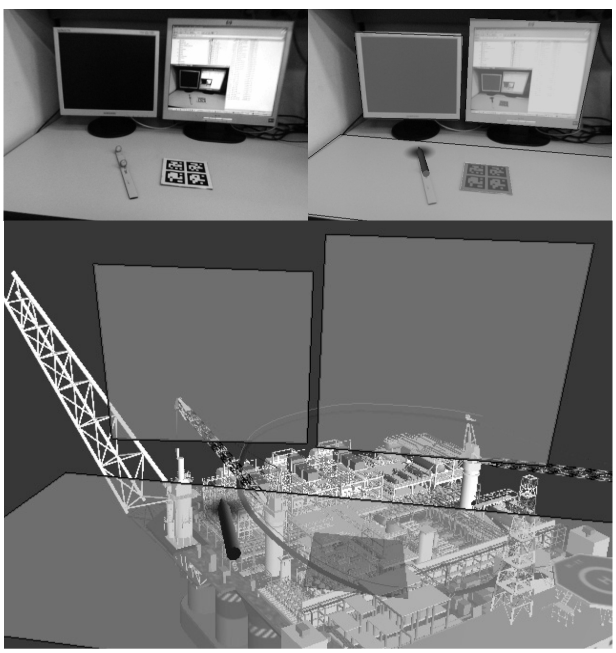

Figure 1. The first two figures show the desktop setup without and with virtual information overlaid on it. The third shows the immersive virtual environment showing the physical interaction boundaries by the use of transparencies.

In the mixed reality continuum, the proposed approach may be considered AV, since the experience is mainly virtual, enhanced by real world information (desktop objects' localization).

This paper is organized as follows. In Section 2 a study about the properties of the interaction space available in the desktop setup is conducted. The potential functionalities for interaction using the spatial interaction space of desktop are analyzed in Section 3. Some experiments are showed in Section 4 and Section 5 concludes the paper.

2. Transparency and the "Foreground 3D"

The representation of the interaction space using transparencies has two primary reasons: to enable the visualization of the virtual environment that may lie behind and, at the same time, provide the information about the boundaries of the physical interaction space.

The use of transparency in 2D user interfaces has been the focus of several researches, most of them related to the approach of See-Through Interface [9], [10]. Related to 3D environments, Zhai studied the use of transparency in 3D graphics and identified its advantages for depth perception [11]. Positive results in navigation performance in 3D environment using transparencies were also verified [12].

Another use of transparencies in user interfaces is related to their dynamic behavior, i.e., the occlusion effect is reduced modifying dynamically the opacity values of a surface that occludes objects of interest. This kind of behavior was studied in 2D interfaces considering the distance to the cursor [13] and also the importance level of regions – content-aware transparency [14].

Harrison and colleagues [10] analyzed how people would use the transparent interface components. They created menus with different transparency levels against different type of backgrounds and analyzed how people distinguish the foreground from the background. Using an analogy with 2D approaches, we mean that in the present work there are two three-dimensional layers, a foreground 3D or something like a forevolume (f3D), and a background 3D or a backvolume (b3D). The f3D is represented by the simplified visual representation of the physical desktop space (using the transparencies) and is also the place where the input of the interaction takes place, i.e., it is not only a visual space but also an interaction space. The b3D is represented by the visual space containing the immersive virtual world scenario. In this work we also discuss how users may distinguish the b3D from the f3D, being also aware of the physical boundaries represented in the f3D.

A potential problem that may compromise the perception of the f3D occurs when the observer is located in a geometrically dense region and there are many objects between the near plane and the f3D. In order to overcome this problem, we created a clipping volume involving the f3D, transforming this region into a kind of cockpit, where the user is "protected" from the environment's objects. Figure 2 illustrates this situation.

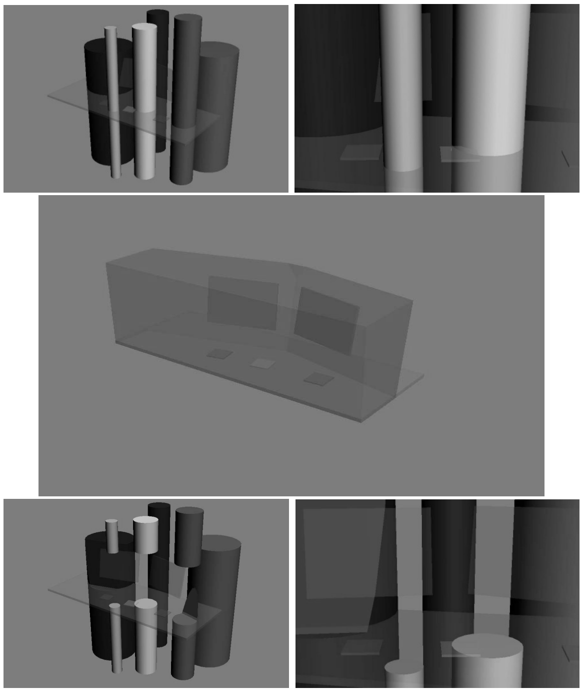

Figure 2. The first two figures show the case of a dense virtual scene without the clipping volume. The second one illustrates the occlusion of the representation of the real objects (transparencies) by the virtual ones. The figure in the middle illustrates the clipping volume and the others show the same scene clipped by this volume.

In the present work, we also use dynamic transparencies, based on the work of Gutwin et al. [13], but extending it to a 3D environment. In this case, we consider the transparency degree as a function of the distance of the 3D pointer from the transparent surface. However, the transparency is not reduced in the whole surface, but on a circular region near the extremity of the pointer, centered in the projection point of this extremity in the surface along the normal of this surface (Figure 3). The nearer the pointer is from the surface, the more opaque will be the circular region. This serves as sign to indicate the proximity of a boundary in f3D.

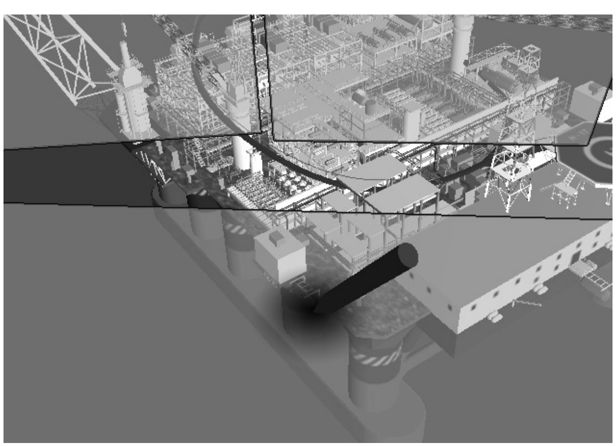

Figure 3. Dynamic transparency region based on 3D pointer proximity.

It is also important to guarantee that the visual stimulus caused by the f3D do not disturb the understanding of the b3D, where lies the virtual world scenario, the focus of the interaction. If the f3D contains appealing visual information, it will probably swerve too much the users' attention from the b3D. Therefore, we opted for a simple geometric representation of the desktop objects (table and displays). The keyboard position is considered as under the table, since more interaction space is obtained. The gained space can be used to include other interaction objects like tangible interfaces to hold digital objects inside the AR environment (called object repositories) and other functionalities in the mixed reality continuum for example interaction techniques related to tabletop interaction.

In [15] the visualization of virtual geometric models in an AR environment to indicate regions with different contexts inside a ubiquitous system was well justified by the concept of Norman's mental model [16]. This model advocates that people create mental representation of everything around to explain what they are. The same argument can be used to explain the use of these transparencies, because these objects could be a visual stimulus that force the subjects to create an abstraction of the physical interaction space without truly seeing the real world boundaries. The position of the transparencies would be visually indicating the intention of the functionally (the interaction boundaries) on the use of AV. Therefore, that abstraction would be used to adequate the interaction techniques in that environment.

3. Potential Functionalities

The use of immersive visualization in a desktop setup by means of HUI provides more functionality for this environment, adding interaction techniques that are typical in IVR. 3D interaction in virtual environments may be basically categorized as: navigation, manipulation, selection, wayfinding, symbolic input, and system control [17]. The implementation of all these interaction categories in a single interaction environment may not be adequate to explore properly the interaction techniques of all of them. HUI appear as an alternative to better explore the 3D interaction categories in a physical workplace, providing different interaction environments.

Due to their heterogeneity, HUI may provide these interaction environments, better exploring the mixed reality continuum. For example, in the context of the desktop HUI, the user may explore both the navigation using mouse and keyboard in WIMP GUIs and also immersive interaction techniques using an HMD in IVR.

The issue of user performance in immersive environments vs. desktop has been studied and some comparisons have been made [18][19][20] and for some applications immersion showed good results. Recent studies indicate that the important is to keep the dimensional congruence [4]. In other words, the interaction technique used to execute a task must match directly the spatial demands of that task. Moreover, some results tend to show that some aspects such as structure of the task and individual differences are considered more important than the kind of display and rendering type [21]. Therefore, the different interactive environments provided in the proposed hybrid environment may be explored differently by each user and, probably most importantly, without imposing the execution in a single interaction environment.

Another advantage of the hybrid environment is to enable the use of established technologies. Examples are symbolic input tasks, such as text editing. This kind of task could be realized in an immersive environment, using especial editors adapted to this environment. However, it is much more productive to use common desktop editors, to which the users are adapted. On the other hand, manipulation tasks could be realized using desktop-based techniques (for example 3D Widgets, ArcBall and 2D Interfaces) using mouse and keyboard. However, it could be more natural to manipulate directly with the hands via tangible interfaces using AR, which gives the sensation that the manipulated object is in the real world. Benko and colleagues developed an application in this sense, enabling interactions using 2D (via desktop) and 3D (via AR) visualizations, as well as the transference of objects between these kinds of visualization [22].

In navigation tasks, exploration and search are frequent objectives, resulting in the creation of a spatial knowledge by the wayfinding task, which is the process of information passing to facilitate the user navigation in an environment. This “navigational” knowledge is normally acquired by means of exocentric views (god’s views) or egocentric ones (first person views) of the digital environment. Several immersive 3D navigation techniques have been developed and the use of part of this knowledge may be useful in a desktop workplace. In that setup, where the user typically remains sit, techniques requiring physical locomotion (for example walking and jump) to reflect the virtual locomotion aren’t feasible. However, there are a variety of navigation techniques that can be adapted to the desktop workplace. Steering techniques (gaze-directed and pointing [23]), route-planning techniques (based on a path specification [24]), a Map-Based or WIM (World-in-miniature) [25], and “grabbing the air” or “scene in hand” [26] are possible because their requirement is a free physical space in front of the user for short-range movements of arms and hands, which is found in the f3D.

The navigation in the IVR would be used for searching and selecting objects of interest, which then can be manipulated in the hybrid environment. Manipulation techniques are executed using egocentric or exocentric views. For precise manipulations the egocentric view has been verified as an adequate alternative [25][27]. Both AR and IVR environments use the egocentric view but, in the context of such hybrid environment, AR seems more appropriate because the visibility of the real environment and real hands provides a more natural bimanual interaction using tangible interfaces holding virtual information. If such kind of interaction were carried on the IVR, additional information would be necessary to represent the real hands and to handle tracking precision problems.

Another advantage in the use of AR is the possibility to drag information (text files, audios, bitmaps, etc…) from the displays on the table to repositories by the use of techniques like *pick-and-drop* and *hyperdragging* [2]. The repositories are tangible interfaces located in the users’ desktop. The use of the AR in this sense follows the ideas of the EMMIE project [3].

An initial scenario using the complete developed hybrid environment is an application for annotations in CAD models. In this scenario, engineers of oil & gas industry may register any kind of annotation on certain parts of a virtual platform. They could use the IVR for navigational tasks to find and reach particular objects, which are selected and moved to repositories. By the use of a transitional interface, the user is then taken to the AR environment to make the annotations and manipulations using the repositories. For example, the user may drag text or audio files from some display and drop them on the object.

4. Early User Experiences

An application managing two interaction environments, one for AR and other for IVR, and a transitional interface between them composed the first prototype of the system in early user experiences. Four subjects were used in that initial empirical phase. Each subject used an HMD with a webcam attached (Figure 4) and initiated the experiment in the AR environment. A 3D pointer and a repository to hold 3D objects were available. The event to start a transition between the environments was a gestural command of taking the 3D pointer near to the HMD. In the IVR there was a visual representation of the repository, the 3D pointer and the f3D (table and two screens). Optical tracking techniques were used to track the pointer, the repository and the HMD. The table and the screens positions and dimensions were measured in advance, and they remained static during the experiment, in order to reduce the processing demanded to track them.

Figure 4. A user wearing an HMD with a webcam attached.

Two kinds of interaction were available in the IVR: raycasting for selection tasks and gaze-directed for navigation. The last one used a direction vector defined by the HMD and the pointer 3D to travel in the immersive environment. For each selection made in the IVR, the selected object was copied from the b3D to the repository in the f3D (Figure 5). When a transition IVR-AR occurred, only the contents of the repository remained visible in the AR environment. The experiment consisted in asking the subject to go to the IVR, navigate to some place and select an object. Then, with the selected object on the repository, the subject should return to the AR environment.

Despite the problems related with register and latency, that initial user experience was positive. The prototype was updated after some initial suggestions, for example, by the visual enforcement of the borders of the transparencies of the table and the screen to increase the distinction from the background, like a cartoon rendering style. Also, the decision for webcams with wide-angle lenses that provide wider field-of-view (fov) was important, because the subjects can visualize a larger part of the real desktop and less movement of the head was necessary to have an overview of the workplace. The fov of the real camera in the augmented reality environment is the same of the fov of the virtual camera inside the IVR so the vision of the f3D got better too (Figure 6).

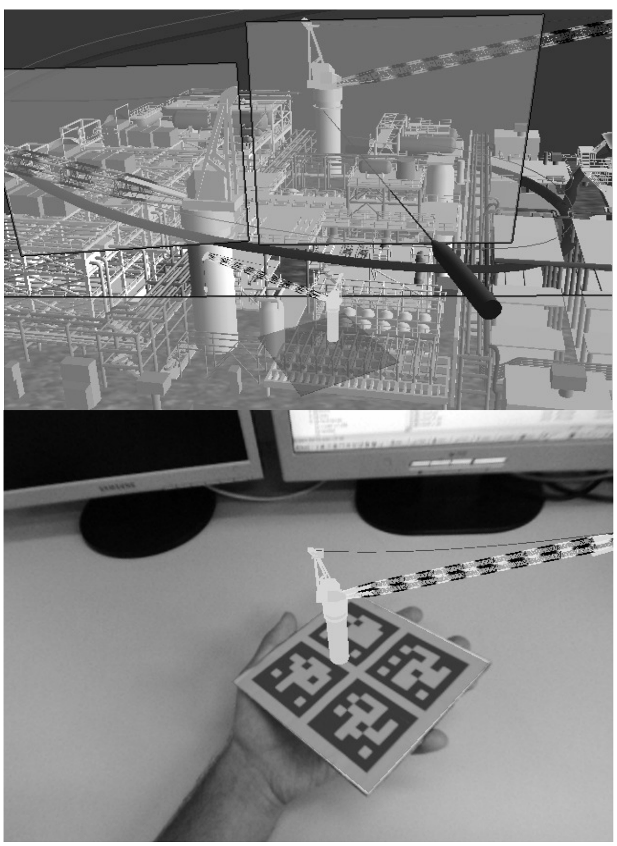

Figure 5. The first figure shows a selection task in the IVR. The second shows the selected object visible in the AR environment.

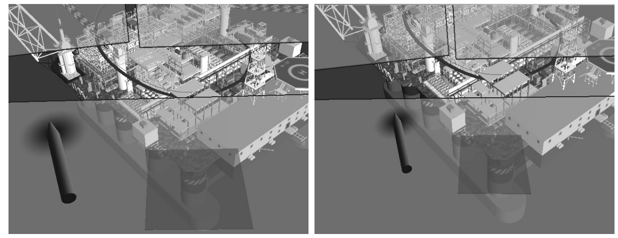

Figure 6. Visions of the f3D with different fovs. The left figure shows a common fov and the other shows a fov using wide-angle lenses.

Some subjects asked for a command to enable and disable the clip process in the f3D, or to disable this effect in some particular object selected by the user. Other suggestion was the inclusion of a transparency shadow of the pointer 3D in the transparency of the table to give more depth sensation without loosing the perception of the b3D. These suggestions will be implemented in the next version of the hybrid interface.

5. Conclusion

This work presented an alternative to enable the use of immersive virtual reality in a common desktop workplace. In order to enable this, augmented virtuality was used to enhance the virtual reality environment with real world information about the physical interaction boundaries by the use of transparencies. These transparencies give the users awareness of the interaction physical space. The importance of the use of this approach in the context of a hybrid user interface composed of two other interaction environments, AR and common 2D Wimp, was discussed, mainly in the context of interaction techniques. An early user experience as an initial empirical evaluation was realized.

The use of a hybrid interface like the one proposed in this work enhances the exploration of the mixed reality continuum because the inclusion of the immersive virtual reality environment, beyond an augmented reality environment and a 2D environment using 2D WIMPS, provides more interaction environments that can complement the interactions of the others and bring particular advantages, for example, for navigational tasks. In a single workplace, there are interaction environments with 2D and 3D features to be used for experimentation and execution of interaction techniques.

As future works, formal tests with different scenarios will be designed and an updated version including subjects' suggestions in the prototype will be implemented.

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