# Experiencing 3D Interactions in Virtual Reality and Augmented Reality

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## ABSTRACT

We demonstrate basic 2D and 3D interactions in both a Virtual Reality (VR) system, called the Personal Space Station, and an Augmented Reality (AR) system, called the Visual Interaction Platform. Since both platforms use identical (optical) tracking hardware and software, and can run identical applications, users can experience the effect of the way the systems present their information to the end user (as VR or AR). Since the systems use state-of-the-art tracking technology, the users can also experience the opportunities and limitations offered by such technology at first hand. Such hands-on experience is expected to enrich the discussion on the role that VR and AR systems (with optical tracking) could and/or should play within Ambient Intelligence.

## Keywords

Virtual Reality, Augmented Reality, Optical Tracking, Human-Computer Interaction, 3D Interaction, Natural Interfaces.

## INTRODUCTION

According to the call for this conference "Ambient Intelligence (AI) represents a vision of the future where we shall be surrounded by electronic environments, sensitive and responsive to people. Ambient intelligence technologies are expected to combine concepts of ubiquitous computing and intelligent systems putting humans in the center of technological developments". This vision of the future is inspired by a very optimistic view on both the usefulness and the capabilities of new technologies. However, in order to distinguish AI research from Science Fiction, we need to ensure that the technologies that are considered can indeed meet the expectations that are raised for them. For the complex technical systems that are involved in AI this poses at least two problems. First, because of the complexity of such systems (that often involve many hardware and software sub-systems), it is very difficult to predict a priori their overall performance. Unexpected effects and complications are the rule rather than the exception. Second, it is equally (or even more) difficult to assess a priori how the targeted (non-expert) users will experience and handle the opportunities and the limitations of the technology in a realistic (i.e., non-laboratory) setting. Partly because of their limited understanding of the technologies involved, users may be unable to handle these technologies in an adequate or satisfying way. The most pragmatic approach towards addressing these issues is to create prototypes that allow to test and to experience the technologies involved. An added advantage of such prototypes is that they make the technologies come to live and hence enrich the discussion on the role that such technologies could and/or should play in future AI systems.

The system awareness (sensing) and user interaction that play a key role in AI can happen at different scales and with different resolutions, ranging from very precise *personal* interaction spaces that naturally emerge around devices like cell phones and personal digital assistants (PDAs), over less-precise *local* interaction spaces such as tables (or desk-tops) and walls where shared activities, especially those involving tangible interaction, can take place, to coarse *global* spaces, such as complete homes and beyond, where remote interaction, mediated through speech, gestures or electronic communication devices, is required. Different technologies are required to address these diverse sensing and interaction requirements. Within this paper we will present two prototype systems that aim at implementing local (tangible) interactions. More precisely, we will discuss two alternative systems that demonstrate identical three-dimensional (3D) interactions in both Virtual Reality (VR) and Augmented Reality (AR). These systems are designed with the explicit goal of making such interactions more natural (i.e., making better use of well-developed human skills for real-object manipulation), and use real (tangible) devices to mediate the interactions with virtual data.

## 3D INTERACTION IN VR AND AR

There are three main aspects that need to be distinguished when discussing 3D interactions, i.e., the sensing of the 3D interaction elements used as inputs, the display (output) of the 3D (virtual) information of interest, and the software applications that link the inputs to the outputs. We will present two systems that share the same sensing and application layer, and that differ only in the output layer. In this way, it becomes possible to assess the effect of this output layer on the resulting user interaction. We briefly introduce both systems, after a short description of the shared sensing technology.

### Sensing

Both systems that we introduce aim at two-handed interactions within 3D data. As shown in Figure 1, the sensing technology allows the user to manipulate 3D virtual objects by means of optically-tracked input devices such as a thimble or pen for point selections, a planar device to position and orient (cutting) planes, a ruler to measure distances, and a cube to position and rotate 3D models.

These input devices (or props) are tagged with infrared-reflecting markers, and tracked by means of well-calibrated infrared stereo cameras. The advantages of optical tracking are that it allows for wireless input, is not susceptible to noise (i.e., electromagnetic interference), and allows for many objects to be tracked simultaneously. The obvious disadvantage is that the hands that are manipulating the input devices may block the line-of-sight of one or both cameras, which can result in a (temporary) loss of the tracking of one or more interaction elements. Note that it is very difficult to a priori estimate the impact of such advantages and limitations on the quality of the interaction.

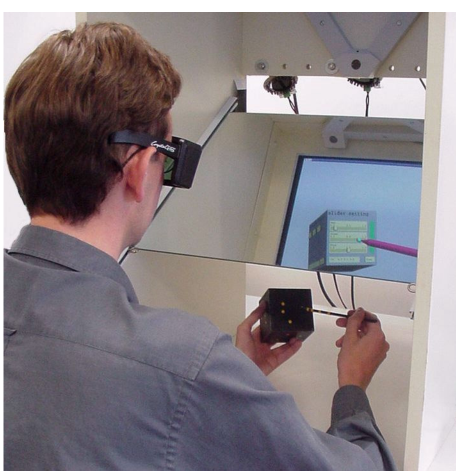

**Figure 1. The user manipulates two interaction devices (pen and cube) in order to control the corresponding virtual objects (displayed in the PSS). The stereo cameras with infrared light sources are (partly) visible in the back.**

### The Personal Space Station (VR environment)

The Personal Space Station (PSS) (Mulder and van Liere, 2002), see Figure 1, is a near-field virtual reality system. The PSS is based on a mirrored display. The manipulations with the virtual data are performed behind a mirror in which a stereoscopic image of the 3D scene, displayed by a high-resolution monitor, is reflected. The user’s head is tracked in order to match the stereoscopic rendering to the head position. Note that, although the user has kinaesthetic awareness of the interaction devices in case of an opaque mirror, a semi-transparent mirror is needed to be able to directly observe the interaction elements and the hands (this is currently not implemented, since it would substantially increases the demands on the accuracy and stability of the optical tracking). The system has similarities to other fish-tank systems (see for instance Arsenault and Ware, 2000). The system pursues an optimal 3D rendering of virtual data, at the cost of some restrictions imposed on the user, more specifically, the need to wear tracked stereo glasses and to be positioned such that his/her hands can work comfortably behind the mirror.

### The Visual Interaction Platform (AR environment)

The Visual Interaction Platform (VIP) (Aliakseyeu et al, 2001), see Figure 2, is an augmented reality system that enables different natural interaction styles such as writing, sketching, manipulating and navigating in 2D and 3D data. The VIP system has evolved from the Build-It system (Fjeld et al., 1998). It employs an LCD projector to create a large computer workspace on a horizontal surface, and uses stereo cameras with infrared light sources, located above the workspace, to track physical objects that are coated with infrared-reflecting material. Whereas the Build-It system can only track the 2D positions of objects on the table, the VIP can track 3D positions on and above the table. The same interaction elements that are used within the PSS system can be used within the VIP. Also unlike the Build-It system, the horizontal workspace of the VIP is a Wacom® UltraPad digitizer tablet of size A2. This tablet can record digital pen movements, which allows the user to perform much more precise actions in the horizontal workspace than are possible within the Build-It system. Precise actions are for instance necessary for handwriting, drawing and sketching. The VIP also provides a second computer display, operated by means of the mouse, on a vertical display. This display is used to present the 3D renderings.

The horizontal workspace is a combined action and perception space (or interactive surface), because the effects of the user actions are visually represented in this space at the positions of the interaction elements. The VIP hence mimics a physical desk-top environment in its 2D interactions, while also providing 3D interactions. However, unlike in the PSS system, the 3D renderings of virtual data do not coincide with the positions of the interaction elements (since these renderings are shown on a separate screen).

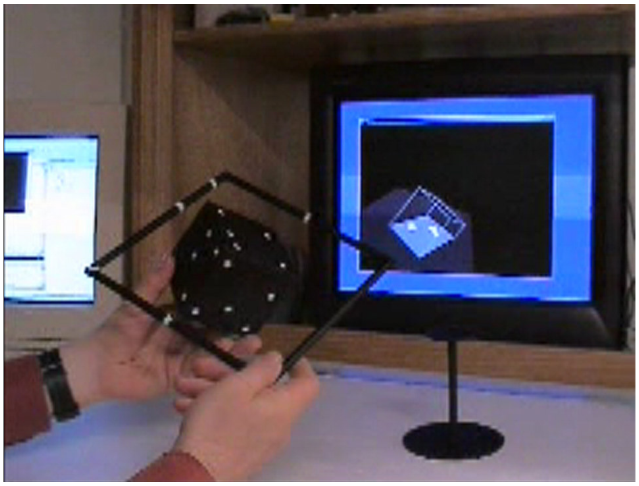

**Figure 2. Interaction within the VIP.**

## DEMONSTRATED INTERACTION TASKS

Two demonstrations will be presented on both platforms. The first one demonstrates two-dimensional (2D) widget manipulations within a 3D virtual world, used amongst others for performing control tasks. The second one shows 3D navigation and manipulation in volumetric data. Although both demonstrations are taken from professional applications, the interaction techniques being demonstrated are sufficiently general to also be relevant for many other application fields, such as for instance 3D games.

### Widget Interface

The 2D widget-interface is comprised of a virtual cube with widgets, such as buttons, menus sliders and message boxes, and a virtual pen to perform selections with (Kok and van Liere, 2004). Two physical interaction devices control these virtual objects: a wooden cube and a wooden pen (or stick), both provided with markers to be recognized by the tracking system. When the user wants to perform control tasks within a 3D application, he can grab the "control" cube and can make adequate selections with the pen. When he is finished, he can move the cube aside, so that it no longer interferes with the application.

Having 6 sides on a cube makes it possible to arrange widgets in groups. Desktop applications often use pop-up menus (such as "File", "Edit", "View"). In our system, these pop-up menus can be made to coincide with different sides of the cube. Popping-up a window in a desktop environment then corresponds to rotating the cube to the appropriate side.

The widget interface also provides the user with feedback about his actions. The virtual pen has a small sphere at its tip. The color of this sphere indicates whether the pen is in contact with the cube or not. The maximum distance between the cube surface and the pen tip that is interpreted as being in virtual contact can be defined by the application. The widgets on the surfaces of the cube also change shape or color when the pen selects them (similarly as in current 2D graphical user interfaces). Most widgets, such as buttons and sliders, are displayed as 3D objects having a height, so that they stick out of the cube. When selected, the height is reduced, just as in case of a real (pressed) button.

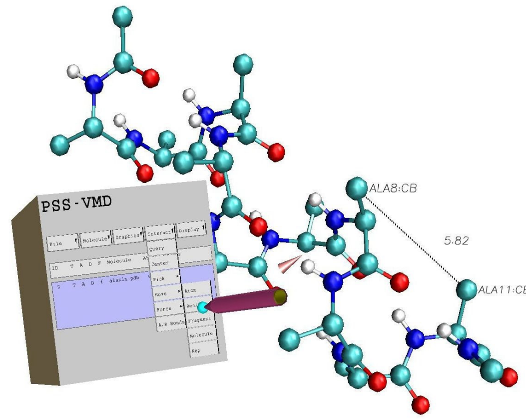


**Figure 3. The widget interface within the VMD application.**

Figure 3 gives an example of the cube-widget interface being integrated into an existing application called VMD. VMD (Humphrey et al., 1996) is a desktop visualization program for interactive visualization and analysis of large molecular structures such as proteins, nucleic acids and lipids. It is widely used in research on these structures. We modified VMD so that it can handle the input from our optically-tracked 3D interaction elements. This modified version of VMD hence allows 3D interaction with molecules. For control tasks, "standard" VMD is equipped with a comprehensive mouse-based user interface containing many pop-up windows with all kinds of widgets. In our modified version of VMD, the interface for control tasks is ported to the "control" cube and settings are performed with the pen.

### Volumetric Data Interface

The volumetric data interface illustrates the power of direct 3D interaction in the area of medical visualization. The input to this application consists of a set of images (e.g. from a CT or MRI scan), defining the volume data. The data can be visualized in three ways: direct volume visualization (left part of Figure 4), cutting plane visualization (right part of Figure 4), or a combination of volume visualization and cutting plane visualization (not shown).

The user (e.g., a physician) holds a cube input device in one hand to position and orient the volume data. This allows him to inspect the data from all sides in a very natural way. For cutting plane visualization the user has a second input device (e.g. a pen) in his other hand to select a plane with arbitrary orientation. The intersected data values are visualized on the plane. The cutting plane visualization allows the physician to inspect the data along non-canonical axes. Furthermore it gives him the opportunity to browse the data quickly, while maintaining a reference as to where the selected plane is situated within the original data set. This interface can be extended with other interaction techniques, such as annotation of interesting contours, interactive segmentation, etc..

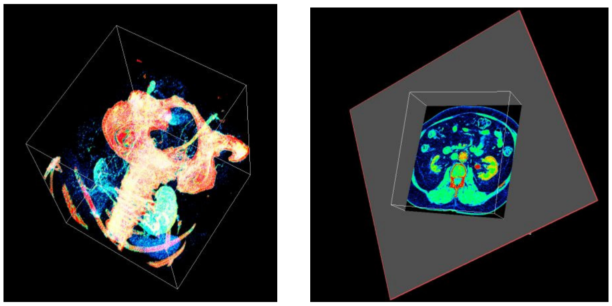

**Figure 4. Volumetric data interface: volume visualization (left) and cutting-plane visualization (right).**

The idea governing the volumetric data interface is to provide the user with the sensation of "the skull in the (non-dominant) hand" metaphor and using this as a reference frame for more precise operations performed with the dominant hand.

## CONCLUSIONS

Within the demonstrations, users can experience important basic interactions, such as 2D widget manipulations in a 3D world, as well as 3D object orientation and positioning, within both a VR and a AR environment. The demonstrations are intended to raise realistic expectations for these basic interaction tasks. On the one hand, such 3D interactions are considered as very natural, since they largely correspond to how people interact with real objects. Therefore, they are considered by many to play an important role in future Ambient Intelligence designs. On the other hand, the finite accuracy and robustness offered by tracking technologies must also be taken into account when considering scenarios that involve 3D interaction. The demonstrations offer users the opportunity to decide for themselves what could and should be the impact of technologies such as optical tracking, VR and AR.

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