Virtual See-through Displays: Interactive Visualization Method in Ubiquitous Computing Environments

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Abstract
Cooperation between multiple information devices is necessary in ubiquitous computing environments. Consequently, visual display interfaces also need to cooperate with each other to help users to understand virtual information in a consistent way. In this point of view, we propose a concept of 'virtual see-through' visualization which supports not only context consistency between multiple visual displays, but also supports personalized and quality supplemented visualizations. We also describe various interaction methods available with virtual see-through displays. By adding information and participant management, we expect 'virtual see-through' will be one of the popular visualization methods for visual display interfaces in ubiquitous computing environments.

Categories and Subject Descriptors (according to ACM CCS): I.3.6 [Computer Graphics]: Methodology and Techniques – Interaction techniques

1. Introduction

Great advances in the personal computing industry are now leading our society into the ubiquitous computing era, passing through the mobile computing age. In ubiquitous computing environments, people are likely to face various information devices simultaneously, including his/her own personal computing devices. Scattered over our everyday lives, these information devices may have various interfaces, not only limited to visual and aural displays or sensors, but also haptic, olfactory and even other new types of interfaces. And, in addition to working independently, they surely will communicate with each other and share information to satisfy the user's computing experience.

There is no doubt that such cooperation is also needed between visual display interfaces, as well. Most of the information devices include visual displays and they vary in their features (e.g. sizes, resolutions, etc.) according to their usages. For instance, large displays could provide an overview of a huge dataset, while hand-held displays with higher resolution could provide details of it. And using both of them together might help users to view virtual information in various aspects.

Under this notion, we propose a 'virtual see-through' visualization of three-dimensional (3D) contents with multiple visual displays, with which users can see different aspects of a virtual content visualized on one display 'through' another.

2. Related work

Providing different views of virtual information within a consistent spatial context is a classical topic in computer graphics and visualization field. Bier et al. [BSP*93] introduced see-through graphical user interfaces. With semi-transparent 2D widgets, named Toolglass and Magic Lenses, users were able to watch and modify graphical objects beneath in different representations. Viega et al. [VCWP96] extended this concept into three dimensions, proposing a 3D volumetric version of Magic Lenses.

Recently, Looser et al. [LBC04] applied similar visualization techniques into augmented reality (AR) interfaces. Different from former see-through interfaces where lenses were virtual widgets, Looser introduced a tangible interface as a physical representation of the virtual lens. Users were able to hold this tangible interface to manipulate the virtual lens and change their views in a natural way.

Slightly different from preceding interfaces that worked as visual filters (or lenses) and focused on providing various visualizations in place, Personal Interaction Panel (PIP) [SG97] and Through-The-Lens [SS02] interfaces focused on using a set of pen and panel interface for manipulating virtual objects and navigating through a virtual space. In these works, physical panels mostly worked as reference planes for two handed interaction.

In comparison to these physical props, virtual see-through displays are actual visual displays on mobile information devices such as laptops, tablet PCs, PDAs, smart phones, etc. Users directly use these devices to add alternative views to the virtual content displayed on other environmental displays such as projection screens, PC monitors, etc. Most similar to our concept, Ubiquitous Graphics [SH05] system showed a two dimensional limited version of virtual see-through displays. This system demonstrated viewing details of the projected images (e.g. maps and paintings) on a hand-held mobile device.

3. Virtual see-through display

3.1 Concepts

The concept of see-through displays was introduced from the AR field. With AR systems, users see the real world through a visual display, the real scene augmented with virtual graphics. Azuma [Azu97] categorized see-through displays for AR systems into two types according to their mechanism how they provide real world views: optical and video. Optical see-through displays use half mirrors to provide the real world view along with computer graphics, while video see-through displays use video images of the real world.

In comparison, ‘virtual see-through displays’ differ from AR see-through displays in terms of that they do not provide the real world view to the user. Instead, virtual see-through displays provide an alternative view of the virtual contents shown on another display behind (i.e. the environmental display), making users feel as if they are looking ‘through’ the display in front (i.e. the virtual see-through display).

The advantages of using virtual see-through displays can be considered in three aspects: context consistency, quality supplementation and personalization.

Context consistency. As shown by virtual lens interfaces [BSP*93][VCWP96][LBC04], visualizing different representations of a single virtual information (or entity) in place is useful for understanding various aspects under consistent context. And virtual see-through displays are useful for visualizing multiple views with consistent spatial context (e.g., users can see X-ray view on a hand-held see-through display while keep watching the whole object visualized on the display behind.)

Quality supplementation. Another advantage of using virtual see-through displays is supplementing the visual quality of one display with another.

Different display devices have different features and varying qualities. Among various features, field of view and resolutions are important measures of pictorial quality in visual displays. Projection displays provide large screens with wide field of view, but usually have limited resolutions. On the other hand, LCD screens on mobile devices have higher resolutions, but they usually have limited field of view due to their small sizes. By using both of the displays in an integrated fashion, one display device could supplement another. For instance, hand-held displays could provide high-resolution detail views, while large projection screens give wide overview of a large virtual image. Similar methods are used for enhancing projection displays [AKHS06] [BGS01].

Personalization. The third merit of virtual see-through displays comes with multiple participants, which would be common in ubiquitous computing environments. Environmental displays are usually used to visualize public information and thus it is hard to provide personalized views. This is especially important for 3D contents (and even more with stereo images) where the scene changes according to the user’s viewpoint. With virtual see-through displays, personalized views can be provided on the see-through display, while the environmental display remains to visualize the public view.

Personalization is not only limited to spatial configurations. Depending on the content, other visualization configurations, such as temporal difference or privacy level, could also be considered for individualizing the view on the virtual see-through display.

3.2 Interaction methods

In order to provide a correct see-through view to the user, knowing the position and orientation of the virtual see-through display relative to the environmental display is necessary. In addition, knowing the position of user’s viewpoint will also help making correct see-through visualization on the hand-held display. Therefore, tracking technology is essential for implementing virtual see-through displays, as virtual see-through displays are needed to be tracked in 3D space.

Taking advantage from tracking, the display itself can be used as a 6 degree-of-freedom tangible interface, instead of adding other interaction devices. As a generic 3D interaction device, virtual see-through displays can be used for most of the 3D general interaction techniques in virtual environments. For instance, for direct 3D manipulation, a virtual see-through display might work as a prop representing a virtual object, while a virtual ray could be calculated from the user's viewpoint to the center of the display for its use in ray casting based interaction methods.

Besides, hand-held computing devices usually include their own input interfaces, such as buttons, pens and even touch screen sensors. Therefore, it would be useful and natural to use those as input interfaces for virtual see-through displays, as well. By using these additional interfaces, many interaction methods from former researches using pen and panels interfaces [SG97] [SS02] [SCP95] can be also applied to virtual see-through displays.

Considering such various possible interaction methods with virtual see-through displays, currently we are planning to categorize them for formal interaction designs.

4. Prototype implementation

In order to show its feasibility, we developed a prototype implementation of virtual see-through display system (see Figure 1).

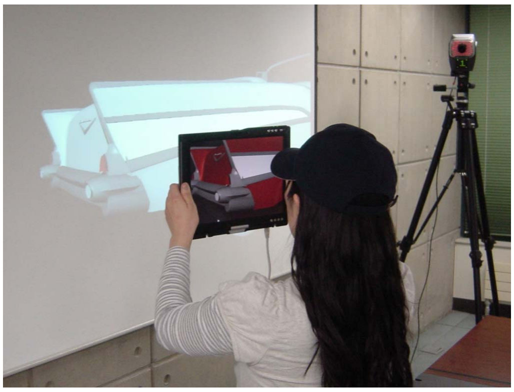

Figure 1: *A prototype implementation of virtual see-through display for a car design review application.*

The prototype system consists of three main hardware components: a projection display, a hand-held display and a tracking system. As an early prototype, we used a normal front projection screen (2m x 1.5m) as an environmental display. And for the hand-held device, which acts as a virtual see-through display, we used a tablet PC. To track the user's viewpoint and the virtual see-through display's 3D position and orientation, we used a motion capture system from Motion Analysis Corporation with four Hawk Digital cameras. The tracking system operated with the update rate of 100Hz, and sub-millimeter 3D positional accuracy.

As a software platform for the prototype system, we used an open source scene graph library, OpenSG (http://www.opensg.org). The projection display and the hand-held display were calibrated to share the same world coordinate frame, and their off-axis projection matrices were calculated according to the user's view point. Although the current calibration process is just a simple measurement of the size and pose of each display, the registration between two displays were good enough for our test application. For other applications that need better accuracy, we are considering adopting common AR calibration methods.

Recently, many virtual reality technologies are used in manufacturing industries. One of the most widely and actively used case is for virtual car reviewing system in car industry. For this reason, we applied our prototype virtual see-through display system to a virtual car design reviewing scenario. Although applications of virtual see-through displays are not limited to car design review, for convenience, here we describe our system focused on this application.

Holding a hand-held display in front of the projection screen, users (designers) can examine a virtual car model under a designing process. On the projection screen, a user can see the overall design of a virtual car at a glance, while the user can also move his/her hand-held display, in front of the projection display, to see the partial details of the virtual car model. Every nock and corner can be seen by moving user's viewpoint or the hand-held display.

Initially, the same car model is shown both on the projection screen and on the hand-held device, aligned with to each other, so that it appears as if the hand-held display is virtually see-through. Meanwhile, users can also choose different representations (or rendering modes) of the virtual car model (such as solid, wire-frame or point clouds) on each display, making the hand-held display to work as a visual lens interface.

In addition to observing the current design, users can also try to modify it (e.g. changing the materials, like color, texture, etc.) For instance, Figure 1 shows the user trying an alternative color (red) on the virtual see-through hand-held display, while the projection screen shows the original color (white) for the car body.

The virtual see-through display can be also used for visualizing cross section views of the car model. In this case, the display itself becomes a prop representing the cross section plane, so that the user could easily manipulate it. Figure 2 shows an example cross section view. The whole car model is displayed on the projection screen (left image) while the virtual see-through display provides a cross section view (right image) of the car. In our prototype system, since we did not provide stereo images, the cross section plane (or the virtual see-through display itself) was visualized on the projection screen for convenience. When using stereoscopic displays for the environmental display, such visualization might not be necessary, since the cross section plane would be fully overlapped with the virtual see-through display itself.

Further 3D interactions with the virtual see-through display are also available. For instance, if the user presses the 'hold' button on the hand-held device, the virtual object within the view is selected and attached to the display, so that users can move the selected object freely by manipulating the hand-held device until the user releases the hold button.

Another interesting interaction with the virtual see-through display is taking snapshots and posting it back after some modification. After positioning the virtual see-through display at a proper position and pressing the 'snapshot' button, the scene visualized on the virtual see-through display is taken as a snapshot. Users might make some modifications to the snapshot using pens or touch screen interfaces provided by the hand-held device, and the modified snapshot could be posted back onto the projection display.

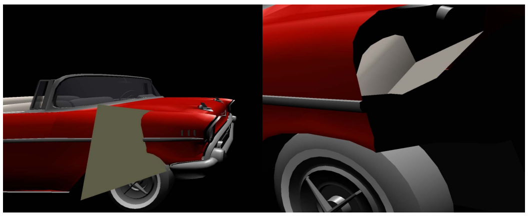

Figure 2: *Cross section view with a hand-held virtual see-through display.*

5. Conclusion and future work

In this paper, we proposed the concept of 'virtual see-through' displays as a visualization and interaction interface for ubiquitous computing environments. We expect virtual see-through features of mobile computing devices will help users to understand, manipulate and exchange virtual information more easily and efficiently.

For future work, we are planning to have user studies to investigate usability issues of virtual see-through displays. And we are also planning to develop participant management features so that users could dynamically join and depart from one environmental display to another. We believe further development of mobile computing devices, wireless networks and ubiquitous tracking sensors will help virtual see-through displays become realized and popular in the future.

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References

[AKHS06] AHLBORN B. A., KREYLOS O., HAMANN B., STAADT O.: A Foveal Inset for Large Display Environments. In Proc. VR'06 (2006), 287-288.

[Azu97] AZUMA R.: A Survey of Augmented Reality. Presence: Teleoperators and Virtual Environments, 6, 4 (1997), 355-385.

[BGS01] BAUDISCH P., GOOD N., STEWART P.: Focus Plus Context Screens: Combining Display Technology with Visualization Technologies. In Proc. UIST'01 (2001), 31-40.

[BSP*93] BIER E. A., STONE M. C., PIER K., BUXTON W., DEROSE T. D.: Toolglass and Magic Lenses: The See-Through Interface. In Proc. SIGGRAPH'93 (1993), 73-80.

[LBC04] LOOSER J., BILLINGHURST M., COCKBURN A.: Through the looking glass: the use of lenses as an interface tool for Augmented Reality interfaces. In Proc. GRAPHITE'04 (2004), 204-211.

[SCP95] STOAKLEY R., CONWAY M. J., PAUSCH R.: Virtual Reality on a WIM: Interactive Worlds in Miniature. In Proc. CHI'95 (1995), 265-272.

[SG97] SZALAVARI Z., GERVAUTZ M.: The Personal Interation Panel – a Two-Handed Interface for Augmented Reality. Computer Graphics Forum (Proc. EUROGRAPHICS'97) 16, 3, (1997), 335-346.

[SH05] SANNEBLAD J., HOLMQUIST L. E.: Ubiquitous Graphics. Emerging Technologies Installation, SIGGRAPH'05 (2005).

[SS02] STOEV S., SCHMALSTIEG D.: Application and Taxonomy of Through-The-Lens Techniques. In Proc. VRST'02 (2002), 57-64.

[VCWP96] VIEGA J., CONWAY M. J., WILLIAMS G., PAUSCH R.: 3D Magic Lenses. In Proc. UIST'96 (1996), 51-58.