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Direct Visuo-Haptic Display System Using a Novel Concept

M. Bordegoni, M. Covarrubias

Dipartimento di Meccanica, Politecnico di Milano, Italy

Abstract

In this short paper we describe a Direct Visuo-Haptic Display System (DVHDS) setup based on a DLP projector, an overhead projection plane and a half silvered mirror. The system is specifically designed for being integrated with a haptic system. It offers a large viewing area with a proper haptic work space ideal for full arm movements in an immersive environment. The system allows superimposing the virtual scene onto the user's perspective of the real world. The system supports controlling the sense of depth and the correction of the distortion of the projected image.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Virtual Reality

1. Introduction

This paper describes the design of a Direct Visuo-Haptic Display Systems (DVHDS) specifically conceived for being integrated with haptic systems, offering users both comfortable sense of perception and depth. The DVHDS is a low cost Augmented Reality display system ideal for full arm movements designed primarily for haptic devices but that can also be used with non haptic hand-immersive applications. As well known, Augmented Reality allows superimposing computer generated graphics (the virtual scene) onto the user's view of the real (physical) world. Several visualization systems have been developed in order to support immersive and AR applications like Reflective Stereo Viewing Display (RSVD), Head Mounted Display (HMD), Head Mounted Projectors (HMP), Hand-Held Displays, Spatial optical combiners, such as planar or curved mirror beam combiners, transparent screens or optical holograms. CAVE and ImmersaDesk create a virtual environment projecting stereoscopic images on screen located between the user and the projectors. Reach-in Display is a low cost CRT-based AR system where the user can touch all the virtual objects in the virtual environment. SenseGraphics 3D-MIW is a portable auto stereoscopic AR display ideal for on the road demonstrations. ImmersiveTouch uses a half silvered mirror and a 22” monitor to create the virtual environment. Each solution has operational limitations and software/hardware interfacing problems including the difference of occlusion. Besdies, most of them doesn’t provide appropriate performances nor satisfies usability issues. The designed system is intended to be integrated within an application for virtual shape modification and evaluation based on haptic interfaces, and supports a proper visualization of virtual and real worlds in the haptic working space. This research work is partially supported by the European Commission, under the FP6 IST SATIN project - Interfaces for Novel product design project (http://www.satin-project.eu).

2. Setup of the DVHDS

The setup of the DVHDS system is designed around a haptic system (consisting of two HapticMaster devices by MOOG-FCS) that is located at the center of the *virtual projection plane*, which is obtained using a DLP projector, an overhead projection plane and a half silvered mirror. The user sees the virtual objects looking through the mirror, as shown in Figure 1. The distortional image projected onto the half silvered mirror can be corrected by rotating the projection plane and/or by operating the keystone function of the DLP projector. This allows us to achieve the desired corrected image projected onto the virtual projection plane.

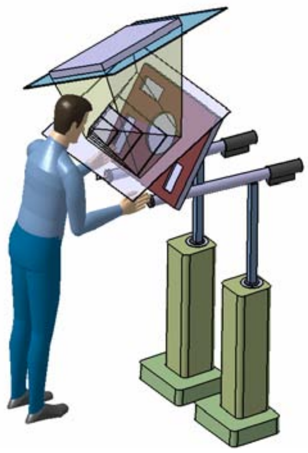

Figure 1: *The DVHDS and the haptic work space.*

The projector used for the system implementation is a DLP projector with a native resolution of 1024 x 768 @ 120 Hz. The half silvered mirror size is 700 mm x 500 mm, and the pixel density (defined as the ratio resolution/size) is 58 pixels per inch. The system provides 75° of horizontal field of view (FOV). According to [Zwe95], visual acuity for displays can be calculated as 20/(FOV*1200/resolution). The acuity of our DVHDS system is 56.25.

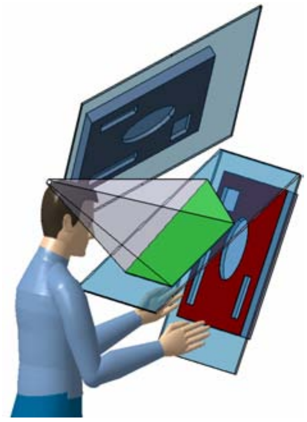

Figure 2: *View of a user interacting with the DVHDS.*

Figure 2 shows a detail of the visualization system setup and of its components. The projector is collocated far from the user satisfying comfort and safety issues; the user is in front of the half silvered mirror so as to have the best position in respect to the display area. The three components have been integrated in such a way to generate an augmented sense of depth which is suitable for VR/AR applications. We can also control the "sense of depth" by modifying the distance of the projecting plane.

3. Operational Principle of the DVHDS

Figure 3 shows the principle of the DVHDS. The light coming out from the projector is reflected on the half silvered mirror (a). At this point the user can see only a trapezoidal figure (b). The light then goes straight to the projection plane that was previously angled in order to correct the distorted image (c) and returns crossing the half silvered mirror again to form the virtual plane where the stereoscopic 3D image is created (d); in fact there are two refractions before of the creation of the virtual plane. This configuration offers good image visualization and allows us to control the sense of depth. If the projection plane is collocated near to the half silvered mirror the user will perceive the virtual object near as well; conversely, if the projection plane is collocated far from the half silvered mirror the user will perceive that the virtual object is far as well. According to [EBSB00], current VR display technology does not well support mixed reality applications. In the case of rear-projection display systems, real world objects always lie between the observer and the projection plane, thereby occluding the projected graphics and consequently obstructing the virtual environment.

Front-Projection has the advantage that physical models can be augmented with projected graphics directly onto the surface of those objects, instead of displaying them in the viewer's visual field. The DVHDS system proposed eliminates this problem thanks to the use of double refraction and the DLP projector.

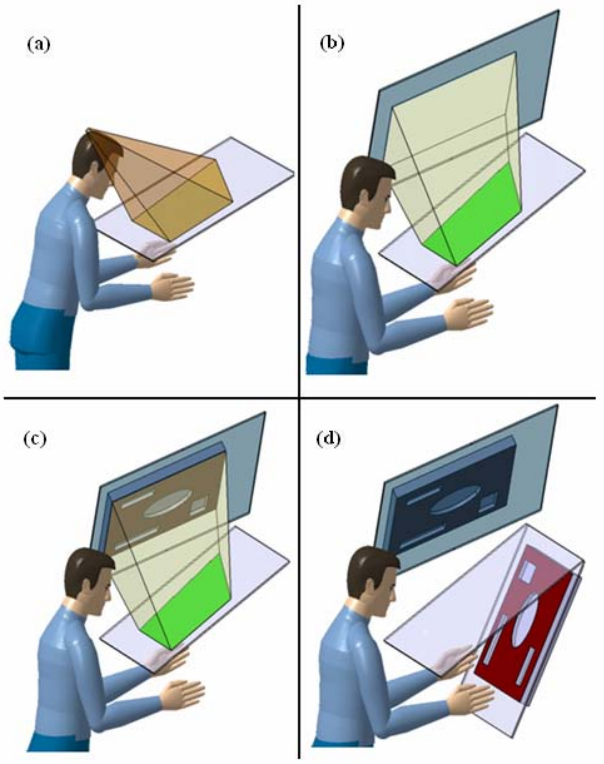

Figure 3: *Final setup of the DVHDS.*

4. Conclusions and future research

The Direct Visuo-Haptic System Display developed is suitable to use in immersive 3D environments. In fact, we can control the sense of depth and the scale of the projected image. We can put the projector in a specific position, far from the user and control the image distortion as result of the new position using both the keystone function included in the DLP projector and the correct rotation of the projection plane. In order to obtain a graphics/haptic collocation we need to add a head and hand tracking system in order to render a correct viewer-centered perspective, in which both left and right views will be perfectly aligned with the user's eyes even when the user moves his/her head. This activity is part of our future research.

5. References

[EBSB00] ENCARNAÇÃO L. M., BIMBER O., SCHMALSTIEG D. and BARTON R. J III.: Seamless 3D Interaction for Virtual Tables, projection planes and CAVEs. *In Cockpit Displays VII: Displays for Defense Applications*, Darrel G. Hopper, Editor, *Proceedings of SPIE* Vol. 4022 pp. 177-188.

[Zwe95] ZWERN, A., "How to select the right head-mounted display", Meckler's VR World, March/April 1995. *http://www.genreality.com/choose.html*