An Autostereoscopic Optical See-through Display for Augmented Reality

Alex Olwal Christoffer Lindfors Jonny Gustafsson

Royal Institute of Technology (KTH), 100 44 Stockholm, Sweden

alx@kth.se, christoffer.lindfors@iip.kth.se, jonny.gustafsson@iip.kth.se

1 Introduction

Augmented Reality (AR) is the concept of combining real and virtual objects, and is traditionally accomplished through a video, or optical, see-through head-mounted-display (HMD). Tracking equipment makes it possible to update the view in the display such that the correct perspective of the virtual objects is rendered to the user.

The intrusiveness of the current display technology is one of the biggest problems in AR systems and our goal has been to develop a minimally intrusive AR system. These ambitions resulted in a novel projection-based AR system with an optical see-through display where a holographic optical element (HOE) is used for autostereoscopy. This is a "walk-up-and-use" 3D AR system where there is no need for the user to wear any equipment. Tracking is not required since the user will see different images depending on the user's view of the display.

2 The Autostereoscopic AR System

Our setup consists of a number of digital projectors that are simultaneously displaying individual images onto a transparent HOE from different angles, as shown in Figure 1. Each image is visible only within a small viewing angle, which allows each eye to be presented with a different perspective. The HOE is the component separating the views in a method similar to the one described by Newswanger [1989]. This display is suitable for AR applications since it provides excellent see-through capabilities, more than enough brightness, and does not interfere with the real scene seen through it.

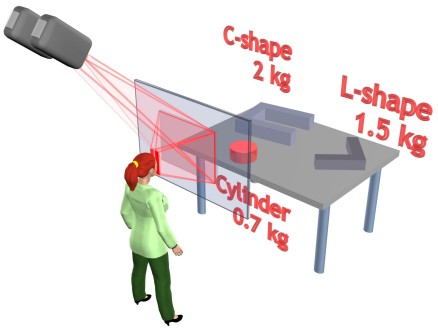

Figure 1. The principle for our display. A transparent holographic optical element in the center of the larger window separates two projected images so that each eye is presented with a different perspective. This creates a stereoscopic image of the virtual annotations and the virtual cylinder.

The HOE forms a holographic image of a light-diffusing screen and when the HOE is illuminated, the reflected light creates a real image of the diffusing screen floating in front of the HOE. The diffusing screen can be made extended in the vertical direction and narrow in the horizontal direction, resulting in a vertical slit. An image that is projected onto the HOE can only be seen if the viewer's eye is positioned so that it is looking through the real image of the diffusing screen. If the projector is directed at an angle to the HOE, then this real image will be displaced in a direction opposite to the location of the projector.

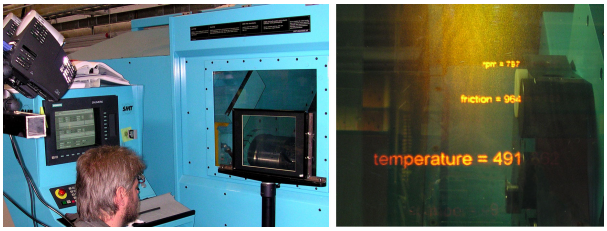

Figure 2. Left: Prototype setup with the display in front of the safety window of an industrial machine. Right: The virtual measurement values are positioned in 3D, seemingly next to the relevant machine parts, as seen through the display.

In this way, by placing projectors at different locations their images can be made to come out separated in space. All the viewing apertures together will make up a viewport in which a viewer can see a three-dimensional image [Gustafsson and Lindfors 2004].

The HOE is produced in an ultra-fine grain silver-halide emulsion, taking advantage of the high sensitivity and large formats available for this material. The size of the first prototype HOE is 30×40 cm.

The number of views is limited to the number of projectors and the views are constrained to lie along the horizontal axis. Thus, our display suffers from the image distortions inherent in all horizontal-parallax-only displays [Glaser 1973]. In addition to the lateral distortion, the apparent depth position of an image point will change when the viewer moves closer to or farther from the HOE. For the type of applications we have tested, where the viewer remains reasonably stationary, we find the positioning accuracy to be more than satisfactory. Our prototype setup is shown in Figure 2.

3 Conclusions and Future Work

Many display characteristics can be chosen when the HOE is manufactured, which makes flexible display configurations possible. The reflection angles can be chosen such that the projectors can be almost arbitrarily positioned and HOEs can be made for either front- or back-projection.

We are currently investigating methods to increase the number of views in a cost-effective manner. This can be done through the addition of off-the-shelf projectors or by other optical means. While the current HOE is monochromatic we aim to develop a full-color HOE while minimizing stray light.

Autostereoscopic optical see-through displays could be useful in numerous situations where sporadic access to AR data is desirable and could become an interesting alternative to traditional HMD-based AR.

References

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3. Newswanger, C., Real time autostereoscopic display using holographic diffusers, United States patent no. 4,799,739, Jan. 1989.