The Daylight Blocking Optical Stereo See-through HMD

In:

© 2008 Association for Computing Machinery (ACM)

P.Santos¹, T.Gierlinger², O. Machui³, A. Stork²

¹Fraunhofer Institute for Computer Graphics Research IGD, Fraunhoferstr. 5, 64283 Darmstadt, Germany
Tel: +49 6151 155 472, Fax: +49 6151 155 139, Email: pedro.santos@igd.fraunhofer.de
²Fraunhofer Institute for Computer Graphics Research IGD, Darmstadt, Germany
³Trivisio GmbH, Dreieich, Germany

Abstract:
In this paper we present an innovative daylight blocking optical stereo see-through HMD. Its outstanding capability is to pixel-wise block incident daylight before super-imposing virtual content on the real scene. By doing so the device allows to seamlessly mix real and virtual content without the well-known effects of other optical see-through displays where real content will always shine through virtual content. To our knowledge related work on daylight blocking displays is very limited and we present the first commercial HMD available.

Keywords: head mounted displays, daylight blocking, mixed reality, augmented reality, virtual reality, interaction, mobility

1 Introduction
The work presented in this paper is motivated by the growing demand for display systems that will work in outdoor conditions providing users with high quality mixed reality visualization. Until today most outdoor visualization systems lack enough brightness to be able to operate in daylight conditions and compete against bright sunlight, so super-imposing virtual content alone is not enough to occlude reality, generally leading to ghosting, which means that no matter how bright the display is, reality will always shine through the virtual content (see Fig. 1).

Fig. 1: Without daylight blocking vs. with daylight blocking

Therefore we chose to occlude sun-light pixel-wise prior to super-imposing virtual content which has led to groundbreaking results in terms of visualization quality and perception. In addition our daylight blocking technique allows to pixel-wise set the level of opaqueness which means that our daylight blocker works as an alpha-channel allowing us to create virtual shadows on real objects. Our work has been motivated and developed within the European research project IMPROVE [1], which tackled mixed reality design review scenarios involving architects and car designers. In this context the main focus was to advance display and rendering technologies, in particular large multi-tiled displays and head mounted displays. One of the goals of the project was to allow architects to go outdoors, on-site and visualize their buildings rendered according to the local daylight conditions. We developed rendering technologies that acquire HDR images of the surroundings, using them as basis for calculation of illumination, reflection and shadows of our models. We developed three HMD prototypes, the last of them leading to the current daylight blocking HMD.
In this paper we will present the rendering technologies developed as well as the driver software for our daylight blocking HMD and the HMD itself.

2 Rendering Techniques

Rendering for mixed reality applications is concerned with the problem of consistently lighting virtual objects in order to seamlessly integrate them into a real environment. Furthermore the image generation must be done in real-time since the viewpoint of the user changes as he moves through the environment. The rendering engine we use to drive the HMD is based on the OpenSG scene graph [2] and employs three algorithms to achieve the integration of virtual and real objects in real-time, namely High Dynamic Range Imaging (HDRI) [3] to capture incident real-world lighting, Image Based Lighting (IBL) [4] to light virtual models from the HDR environment photographs and Precomputed Radiance Transfer (PRT) [5] for calculating dynamic soft-shadows.

2.1. Driver

From the rendering point of view the third HMD prototype consists of four displays that need to be fed. For each eye there is one color display which has a resolution of 800x600 pixels and a light blocking TFT with a resolution of 1024x768 pixels. Each pair of color and alpha display is accessed via a single DVI input and expects an image of a resolution of 2048x768 pixels. We want to drive all displays from a single PC which means that we have to provide a resolution of 2048x768 on each DVI output of the graphics board. We do this by defining a custom display resolution of 4096x768 (which is possible in current Nvidia display drivers) and configure the desktop of a Windows PC to run in “horizontal span” mode. This setup allows us to create a full-screen window of the needed size of 4096x768 pixels. In this high resolution window we create four viewports. The layout of the viewports is shown in Fig. 2. From left to right the viewports of the window are: left eye color (800x600), left eye alpha (1024x768), right eye color (800x600) and right eye alpha.

The rendering is performed using frame buffer objects (FBO). First the scene is rendered into an FBO. Afterwards the FBO texture is applied to a view-aligned quad that fits exactly into the color viewport of the left eye (the cameras used for the view-aligned viewports are orthographic). The texture coordinate of the view-aligned quad are scaled such that the rendered image fits into the top-left 800x600 pixels of the viewport. Next the FBO texture is applied to a view-aligned quad of the alpha-channel viewport. We render the texture using a shader that calculates alpha values from the original rendering output and writes them to the RGB frame-buffer of the alpha-viewport. This procedure is repeated for the right eye. To calculate the alpha values we define shadow receivers in the virtual scene which are used to blend virtual shadows over real-world objects.

2.2. Example

In the example shown in Fig. 2 there is a shadow receiving plane below the car model. The material of the shadow receivers is diffuse white. The alpha value for each fragment is calculated by performing the lighting calculation twice: First the receiver is rendered without shadows and the resulting color is stored. Second the receiver is rendered with PRT shadowing turned on. The ratio of shadowed color to unshadowed color is used as alpha value.

3 Daylight Blocking Display

To the knowledge of the authors, the only comparable works previously done are some first prototypes by Kiyokawa et al. [6] and applications for workbenches from Mulder et al. [7] that also explicitly use the light-blocking technique. In contrast to real daylight blocking most technologies only augment the brightness of the virtual content reaching the eye as to provide a perception of occluded reality. One of the most effective ways is found for example in Microvision Retina Scanners [8]. In contrast to the previous approaches to daylight blocking our solution is lightweight and portable allowing for mobile mixed reality applications, such as on-site architectural design review or indoor automotive design review (see Fig. 3). The most striking difference to conventional displays is the fact, that only by using light-blocking it is possible to create virtual shadows on real objects, which is not possible with conventional display technologies.

Fig. 2: Daylight Blocking Display Driver

Fig. 3: Kiyokawa 2001, Kiyokawa 2003, Our HMD 2008
3.1. The Display

The innovative contribution of this work (see Fig. 4) is the application of two LCD panels per eye with two distinct functionalities. The first panel (the daylight blocker) is located at the beginning of the optical path where real world light enters the system. It is able to pixel-wise block real light with an 8 Bit alpha-channel. The second panel is used to create the virtual image which is mixed with the light passing the daylight-blocker. The current display resolution is SVGA (800x600) in true-color, while the resolution of the daylight-blocker is XGA (1024x768) with 8 Bit grayscale.

Due to patent pending issues we cannot disclose the optic concept in more detail in this paper.

The final decision on the LCDs used was influenced by the availability of LCD panels, the maximum flexibility and the best brightness. Therefore we selected the transmissive LCD for pixel based real light blocking inside binoculars from Sony in XGA resolution. The specifications are as following:

- Sony LCD „LCX017AL“
- Resolution: XGA (1024x768)
- Type: Active matrix polysilicon TFT-LCD
- High contrast ratio with normally white mode: 250 (typ.)

For the micro-display generating the virtual image of binoculars (info channel), because of the planned optical scheme only self luminous or back-lighted displays were suitable (reflective types were not practical). From the technical point of view the specifications, in terms of resolution, pixel size, diagonal and aspect of ratio, should match the selected micro-display of light blocker. On the other hand also availability and price where influencing the decision. The chosen display is a backlight illuminated transmissive LCD from Kopin in SVGA resolution for generating the virtual image of binoculars. These are the specifications:

- Kopin "CyberDisplay 1440K"
- Resolution: SVGA (800x600)
- Brightness: >350cd/m²
- Contrast: 100:1
- Fill factor: 60% (more crisp image)
- Active pixel area: 12mm × 9mm
- Power consumption: 1,2W

Fig. 4: Daylight Blocking Display

The final device consists of two DVI inputs, each receiving the virtual image information and the alpha channel information for the respective eye.
The technical specification of the device is as follows:

- **FOV (field-of-view) virtual image**: ~26° diagonal, ~20.8° vertical, ~15.6° horizontal
- **FOV (field-of-view) reality**: ~33.4° diagonal, ~26.7° vertical, ~20.0° horizontal
- **Distortion**: 3.6% diagonal, 2.3% vertical, 1.3% horizontal
- **Exit pupil diameter**: 6-8mm
- **Eye relief**: 15mm
- **Virtual image distance**: 2000mm
- **Quality of image (diameter of blurr pixel)**: 0.38' center, 6.6' upper corners
- **Theoretical brightness of reality**: ~5% transparency
- **Theoretical brightness of virtual image**: ~85cd/m²
- **Offset reality axis to eye**: ~46mm (vert.)
- **Dimensions (WxDxH)**: 128mm x 155mm x 95mm
- **Weight**: 1040g

Integrated into the device is a small VGA camera "VRmC-3plus" from VRmagic to be used for marker-less tracking in outdoor mixed reality environments.

## 4 Conclusion

To our knowledge our daylight blocking device is unique in the sense that it is an economic choice when compared to other display systems, portable, lightweight and ready to be used in mobile outdoor mixed reality scenarios. In addition it features an 8-Bit alpha channel for daylight blocking so we are even able to cast virtual shadows on real objects. The technology developed is innovative and presents a real benefit to outdoor mobile mixed reality applications making it possible for the first time to seamlessly mix real and virtual content in good quality, even in bright sun-light outdoor environments.

## 5 Acknowledgments

This display has been developed within the European research project IMPROVE IST-2003-004785.

### References


Last visited: 15.04.2008