Walk-through Mixed Reality Displays

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CHI 2013 Workshop on Displays Take New Shape: An Agenda for Interactive Surfaces, April 28, 2013, Paris, France.

Abstract
Why a display should be physical in the first place? Immaterial mid-air displays are more suitable for many situations than impenetrable monitors or display walls. Interactive mid-air projection screens in various sizes are becoming feasible alternatives for displaying information and interacting with it. We have created a Kinect-based interactive and virtual reality system for the FogScreen. We also explore mobile projection onto it.

Keywords
Augmented reality; mixed reality; transparent displays; fogscreen; projection; spatial user interfaces

ACM Classification Keywords
H.5.1 Information interfaces and presentation (e.g., HCI): Multimedia information systems—artificial, augmented, and virtual realities; I.4.0 Image processing and computer vision: General—image displays; H.5.2 Information systems: User interface.

Introduction
Many techniques can create an impression of a 3D image floating in mid-air. Most such displays are not truly mid-air or penetrable. There are many water, smoke and fog screens and patents since the end of the 19th century [e.g., 1, 2]. The image quality of these screens is usually low or the overflowing wetness makes many of them impassable.

The optimal method for forming a particle display [3] enables high-quality images to float in free space. The light from rear-projection is scattered through this sheet of fog, creating an image in mid-air on the screen plane. The images can be walked or reached through, as the screen is unobtrusive and “immaterial”. It can optionally be two-sided with different images on each side of the screen. Also stereoscopic projection is possible, which requires stereoscopic eye-wear. A dark backdrop improves the visibility of the projected image a lot. These fogscreens [4] create stunning effects among general public or on stage, and they are often described as “holograms” by general public and media.

In this paper we describe our Kinect-based interactive and virtual reality system for the FogScreen. We also explore mobile projection onto it.

Mid-air touch screens and mixed reality

Many types of sensors can be used to create interactive mid-air displays. However, there are no off-the-shelf user tracking solutions for the fogscreen. Some tracking products are fairly suitable, but some modifications are always needed due to the immaterial nature of the mid-air screen or disturbances caused by the fog. Also the accuracy, price or other features of the trackers often leave much to be desired.

We have created a Kinect-based system, which enables low-cost user tracking and advanced features for the fogscreen. The Kinect-based setup allows the user to “touch” and interact with the projected objects and scenes. Figure 1 shows a 2D touch screen usage with a hand-drawing application.

Figure 1. Kinect-based mid-air touch screen with drawing.

Our Kinect tracking software enables also mid-air virtual reality, where the viewer’s head position is tracked in three dimensions. The projected 3D graphics is updated accordingly in real time. Also various kinds of augmented reality and mixed reality are possible, as well as novel spatial user interfaces.

Figure 2. Kinect-based mid-air VR screen. When the viewpoint moves, the augmented mid-air 3D object remains “locked” to its real-world position and looks like a natural part of the environment.

Figure 2 shows how the mid-air VR image of a space-ship augments an office room in a fixed position. The 3D objects become embedded visual elements of the environment as if they would really float in thin air. This enables magical mid-air gaming, next-generation digital signage, etc.

Kinect can differentiate users and their finger, wrist and hand postures, and handedness [5]. The screen can also be turned on and off depending on e.g., the proximity of viewers [6].

Mobile Projection onto FogScreen

Hand-held or body-mounted pico projectors are used on many AR experiments. For example OmniTouch [7] uses a body-worn projection / sensing system. Sixth-Sense [8] system projects information on basically any near-by object. Pico projectors are also embedded to some modern smart phones.

Mid-air AR projections onto FogScreens [9] with fixed projectors create unobtrusive augmented reality. The system is a little similar to transparent LCD displays, but the image can be reached or even walked through.

Head-mounted projective displays (HMPD) e.g., [10, 11] require retroreflective material to be strategically placed on the environment. As the retroreflective material sends almost all the projected light back to the viewer, it creates a bright but private view for the user.

Head-mounted pico projector (HMPP) without retroreflective materials is little explored display concept. It enables to show augmented information onto unprepared environments in the real world, even though HMPP has also some limitations. Some HMPP experiments exist [e.g., 7, 12, 13].

A HMPP (or a hand-held projector) can be used also to project images onto the FogScreen (see Figure 3). Normally a ceiling-mounted projector is used for the Fog-Screens, but a HMPP moves with the user. It can supplement normal projection.

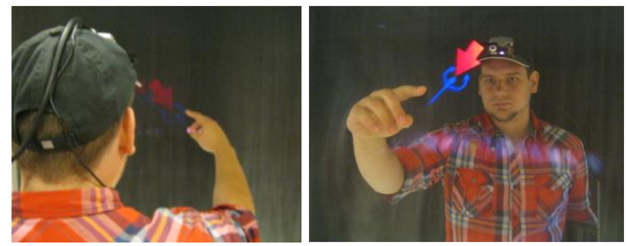

Figure 3. Projecting objects onto a FogScreen (teacher's and students' views)

Unfortunately the Mie scattering of light on the screen produces a very faint picture on the projector's (HMPP viewer's) side, but viewers on the other side of the screen see a significantly brighter image. The HMPP and the dim Mie scattering together mean that HMPP alone is too weak for a primary user. It can however supplement and augment a brighter projection.

One intriguing issue with HMPP projection is that it enables new kinds of interactivity. Earlier interactive systems for the fogscreen have focused on physical position of hands or other objects. HMPP interaction enables interaction based on projected light.

As the pico projector is mounted on head, head movements can become exaggerated in the projected image.

Some stabilization of the image could be made based on camera and other sensor data, but this is an issue for our future research.

The HMPP (or a hand-held projector) used with a FogScreen suits well e.g., to classroom situations, where the teacher is on the other side of the screen than the students. The teacher can show things on the unobtrusive mid-air screen in the middle and interact with the projected objects, while teacher and students are continuously facing each other. Thus blackboard or whiteboard becomes an interactive "fogboard". Mobile projection onto the FogScreen would be very useful also for meeting rooms and other such social, collaborative or teamwork situations.

Conclusions

Mid-air particle displays are emerging "hologram" displays, which create convincing 3D objects and virtual environments which float seemingly in mid-air. The improved Kinect-based tracking enables low-cost interactive and virtual reality screens.

Mid-air screens with 2D or 3D tracking have potential for novel games, digital signage, entertainment, novel interaction methods and mid-air user interfaces [14]. Mobile projection onto the FogScreens can supplement and augment a brighter projection, while teacher and students can continuously face each other.

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