

# An Immaterial, Dual-sided Display System with 3D Interaction

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Figure 1. Our immaterial dual-sided display system in action, running several demo applications. *Left to right:* a) Consigalo. A multiplayer game with responsive soundtrack and touchscreen-style interaction that exploits the dual-sided aspects of our system. b) Rigid body simulator. An easy-to-use mechanical dynamics simulator that allows you to interact with objects in a physically intuitive manner. c) Virtual forest tour. A portal into a virtual world with thousands of dynamically rendered trees, where the user can walk and look around.

## ABSTRACT

We present an interactive wall-sized immaterial display that introduces a number of interesting possibilities for advanced interface design. The immaterial nature of a thin sheet of fog allows users to penetrate and even walk through the screen, while its dual-sided nature allows for new possibilities in multi-user face-to-face collaboration and pseudo-3D visualization.

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**Additional Keywords:** display, fogscreen, immaterial, walk-through, reach-through, two-sided, transparent, interactive

## 1 INTRODUCTION

Interactive screens, objects and user interfaces that seem to float in mid-air can be generated in a variety of ways. Traditional AR and VR often use head-worn displays where 6DOF head tracking is used to provide the correct perspective. Artifacts such as mis-registration and lag are commonly experienced problems that detract from the sense of presence in the VR or AR scene.

The interest in non-encumbering technologies has led to several related systems, such as volumetric displays, primitive immaterial displays based on water, smoke or fog [8, 3, 12, 1], and large translucent interactive systems [6, 13] using transparent materials (such as [4] and [7]). The Heliodisplay [5] is a medium-sized (22-42 inches) immaterial display based on the same principle as the patented FogScreen. Single-sidedness, smaller format and table-top setup, makes it less suitable as a walk-through multi-user interactive system.

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Our contribution is a novel interactive, dual-sided, wall-sized system that allows multiple unencumbered users to naturally manipulate objects floating in midair, as shown in Figure 1. Two individual, but coordinated, images are projected onto opposite sides of a thin film of dry fog and an integrated 3D tracking system allows users on both sides to interact with the content, while the non-intrusive and immaterial display makes it possible to freely pass physical objects between users or move through the shared workspace. Our system opens up possibilities for a wide range of collaborative applications where face-to-face interaction and maximum use of screen estate is desirable, as well as the maintenance of individual views for different users.

## 2 THE IMMATERIAL FOGSCREEN

The FogScreen is an optimal, patented method for forming a physically penetrable particle display [9, 11] that allows projection of interactive content to appear floating in free space. The basic principle is the use of a large non-turbulent airflow to protect a flow of particles, such as dry fog, inside it from turbulence. The resulting thin, stable sheet of fog enables projections on a screen that is dry and feels like moderately cool air. The light from a standard LCD projector is scattered through this sheet of fog, creating a rear-projection image.

### 2.1 Dual-sided Projection and Interaction

The FogScreen's opacity depends on many parameters such as fog density, projector and image brightness, and background of the viewing area. Very little of the projected light actually reflects from the fog layer back towards the projecting source. This makes it possible to simultaneously display different images on the two sides of the FogScreen using two opposing projectors.

Dual-sided systems present many new opportunities in application interfaces. Our elastic surface deformer application renders both sides of a 3D object on the two sides of the FogScreen, creat-



Figure 2. The support for dual-sided projection allows two independent images to be projected on each side, such that a 3D application can render two interactive views for a pseudo-3D effect.  
Left: Front view. Right: Rear view.

ing a more convincing sense of presence of the virtual object in the physical environment, as shown in Figure 2.

Collaboration among multiple people within a single application can be greatly enhanced by a dual-sided display. With our dual-sided system, the same interface and layout can be presented on both sides of the screen, but text and images can be properly oriented so all users can actively participate. Collaboration is also encouraged through its inherent support for face-to-face interaction and eye contact.

## 2.2 Walk-through and Reach-through Interaction

The immaterial nature of the display is important for enabling new interaction possibilities. While two traditional displays mounted back-to-back could present a similar pseudo-3D display to multiple users, the opaque displays would prohibit users from effectively collaborating across the two displays by obscuring users' views of each other, distorting speech, and making it difficult to pass physical objects across the display. This permeability of the FogScreen is important not only for collaboration but also for a variety of new interfaces.

The ability for a user to walk completely through the FogScreen makes it appropriate as a portal in virtual or mixed reality environments. A CAVE with a FogScreen as a wall, for instance, would allow the user to easily enter the virtual environment from the outside. Interfaces could also initiate actions when certain objects are moved through the display. Our system could for instance support the Magic Lens metaphor [2] – e.g., objects that are moved through the screen could get augmented with graphics. This would create an intuitive way to add virtual annotation and augmentation to physical objects without requiring the user to wear any equipment or learn an interface to operate.

## 3 3D INTERACTION

We developed several applications for our system that we presented at SIGGRAPH 2005, Emerging Technologies (See Figure 1 and 2). A vision-based 3D tracking system (WorldViz PPT) was used with custom-built wireless controllers to enable 3D interaction. The goal with each application was to explore a different interaction mechanism using the unique capabilities of the FogScreen and our input devices.

**The Rigid Body Simulator** lets users intuitively interact with realistically behaving virtual objects. Our application simulates a low-gravity environment using standard mechanical dynamics, where virtual rigid bodies bounce around as they collide with user-controlled paddles.

**The Virtual Forest Tour** explores the concept of a portal to a virtual environment with a first-person point of view using our 3DOF wireless controller for interaction. The user navigates in an

aesthetic landscape where thousands of plants are realistically rendered and animated with the Planta SDK [10].

**Consigalo** is an engaging multiplayer game where the user touches the screen to grab and drag objects at a location, or moves away from the screen to release objects. Collaborative face-to-face 3D interaction allows two-sided play – one can switch sides by moving through the screen while interacting with the content.

**The Elastic Surface Deformer** allows the user to stretch and sculpt, as well as to move and rotate, an elastic 3D model of a human head. The front and back views are projected on opposite sides, such that the user can walk through the screen to see what the object looks like from the other side, in a pseudo-3D fashion.

## 4 CONCLUSIONS AND FUTURE WORK

The FogScreen has shown itself to be a captivating display technology that immediately generates interest and excitement in the audience. The feedback from SIGGRAPH 2005, Emerging Technologies was unanimously enthusiastic about the display system as well as the potential for the interface technology. Ongoing work includes improved image quality, stereoscopic rendering, and haptic feedback. In the interest in developing a fully volumetric 3D display, we are currently investigating the use of multiple FogScreens to allow images to occupy a tangible physical volume surrounding the user. This would overcome a fundamental limitation of existing volumetric displays, allowing the user to become fully immersed in the 3D visualization, while enabling direct manipulation of the scene.

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