MUST-D: Multi-User See Through Display

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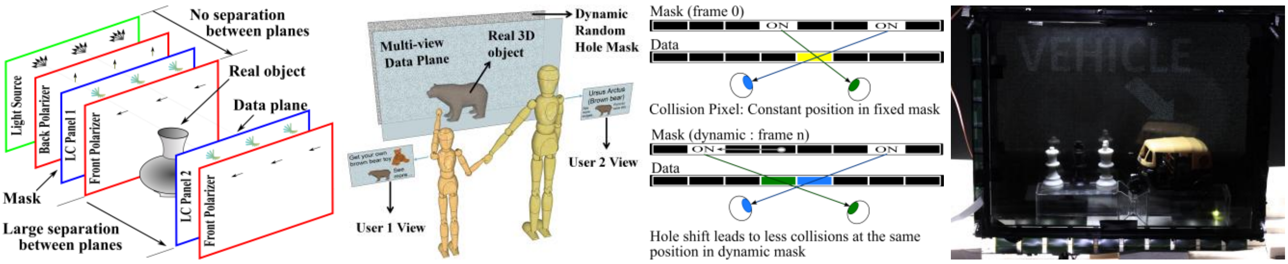

Figure 1: (a) Exploded View (b) Multi-view Visualization (c) Collision pixels and dynamic mask (d) MUST-D Prototype

ABSTRACT

In this paper we present MUST-D a multi-user see-through display that allows users to inspect objects behind a glass panel while projecting view dependent information on the glass to the user. MUST-D uses liquid crystal panels to implement a multi-view see-through display space in front of physical objects.

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General terms: Design, Human Factors

Keywords: See-through, Random hole displays, multi-view

INTRODUCTION

See-through displays allow users to look at physical objects placed behind a glass panel while at the same time displaying digital content on the glass surface. See-through displays can enhance a viewer's experience through the glass. For example, with a shop window the display can provide pricing information or reviews of the product. A further example would be a showcase in a museum where the digital content is the historical information about the artefact. The displays can also be useful in displaying extended information to an audience viewing a demonstration of a specialized task.

While past technical solutions to support mixed-realty applications [1] have mostly focused on using HMDs we are primarily concerned with digital augmentation that does not rely on wearing or carrying special devices. DigiScope [3] is an early implementation of a single-viewer system that uses a transparent see-through display to allow to see information and physical objects through a transparent screen. Wilson [6] proposes image-processing solutions to allow users to point at the screen or at the physical object behind such a screen.

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However see-through display systems have been limited to supporting single user applications. The information presented is only relevant to one of the viewers. Yet, the most beneficial aspect of a see-through glass in a museum or a retail setting is in its ability to support multiple users with distinct views— in this manner all users can view and experience the artefacts behind the glass simultaneously (Figure 1(b)).

In this paper we present MUST-D a multi-user see-through display as shown in Figure 1(d). MUST-D allows users to inspect objects behind a glass panel while projecting view dependent information on the glass to the user. MUST-D consists of two liquid crystals (LC) as shown in Figure 1 (a). We use the front LC as the data display whereas the back serves as a dynamic mask. The mask and data views are calculated using optimization such that data visibility is maximized for specific viewpoints while conflicts are minimized.

MUST-D draws its inspiration from the IllusionHole [5] and Tabletop Autostereoscopic Display system [4]. IllusionHole allowed multiple users to look through a large circular hole (which acts as a mask) placed at a distance from a tabletop display thereby allowing users at different locations around the table to look at different parts of the screen. Gu et al. [4] extend this by replacing the single large hole with a flat panel consisting of a collection of fixed random dots that each serves as a mask.

MUST-D

Dynamic Random Hole Display

MUST-D requires two elements to function properly. These are: a) hole mask that restricts the amount of data visible to each user; b) data panel where data for multiple views is presented simultaneously. Distinct views are generated as only parts of the data panel are visible through the mask. A fixed hole mask like in [4] and [5] blocks parts of the data plane from being viewed by an user whereas a dynamic random hole display like

MUST-D can allow coverage of the entire screen by constantly changing the hole mask from frame to frame.

A LC panel with crossed polarizers attached to its two sides can regulate its translucence. Using variable black-white patterned image, we can control the hole size and position of the mask. The user-data is output onto another LC with only the front polarizer attached. In this arrangement, a single data pixel is only visible to the user if the corresponding mask pixel on the rear LCD is on. This two LC panel setup can work as dynamic random hole display.

Poisson Disc Noise Hole Patterns

A standard side effect of random hole displays is that more than one user can view the same pixel location on the displayed image through different holes. Such a pixel is called a 'collision pixel'. It is possible to algorithmically minimize the effect of the collision pixel for a fixed mask [4]. As the number of users increases the number of collision pixels increases and the displayed image quality degrades gradually.

In a dynamic random hole pattern, the spatial positions of the holes change with time. This ensures that the collisions (being inevitable) occur in a random manner and are not constantly fixated on a single pixel as seen in Figure 1 (c) The system can handle more active users with less image degradation. The implementation still leaves room for error diffusion techniques while operating on each frame.

The dynamic random hole pattern requires a blue noise function providing full coverage of the display area over time. We choose to implement the Poisson Disc Noise algorithm proposed by Bridson [2] for this. This algorithm covers >95% of the display area over 10 iterations.

3D AR Requirements

The system has to be see-through to be able to augment real 3D objects. The spatial arrangement of the two LCs with a large gap (>300 times pixel pitch) allows an object to be placed in the gap. If the object was placed behind the whole setup, the mask state would determine the visibility of the object. This would affect the viewpoint of a user only interested in the object and not the 2D information.

IMPLEMENTATION

MUST-D is implemented using two 17" (1280x1024px) Matsushita LCD panels. We removed the rear polarizer for the front LCD. The light source consists of light waveguides sourced by white LEDs.

MUST-D pre-computes 5 sets of random dot patterns at start-up and sequentially displays each one for 1/16s on the rear LC. A thread updates the patterns sequentially with a new pattern every 250ms. The eye-positions of the active users are fed to a Cg based program running on the NVidia GEForce 8400 GPU.

The Cg program also receives the hole patterns and the views as textures. For each texture point of the data image and each eye, the Cg program evaluates an equivalent texture point on the active hole pattern. If it evaluates to a hole, the data texture colour is retained for processing. After this the program resolves the collision pixels and outputs the resulting colour to the data screen.

CONSTRAINTS

The system uses off-the-shelf LC panels and thus suffers from an interference artefact. This is due to colour filters which generate the colours during normal operation of the LC. They are part of the transistor layer coating of the LC panel and cannot be removed. The polarizers, which are glued on, can however be 'easily' removed.

Light attenuation is apparent at viewing angles beyond 60^o of normal to LC plane as the LC panels are only specified to provide 10:1 contrast ratio (at 75^o). These constraints can be mitigated if dedicated LCs were used instead

The configuration of MUST-D allows augmenting the surroundings of the object but not in-object annotations as the object itself blocks polarized light from the mask. This is an acceptable configuration for the benefit of multi-viewer and see-through capability.

CONCLUSION AND FUTURE WORK

MUST-D is capable of generating multiple views and dealing with collision pixels in real-time. Currently it uses pre-programmed 3D viewpoint positions. The logical extension is to use a sensor such as the Microsoft Kinect to estimate the eye positions from head and image information. With this, MUST-D can allow the users to change their position in front of the MUST-D. We intend to explore mid-air gestures to allow rich interactions with MUST-D.

REFERENCES

1.Azuma, R. A Survey of Augmented Reality. *Presence: Teleoperators and Virtual Environments* 6(4): 355-385. (1997)

2.Bridson, R. Fast Poisson disk sampling in arbitrary dimensions. ACM SIGGRAPH 2007 Sketches. San Diego, California, ACM: 22.(2007)

3.Ferscha, A. and Keller, M. DigiScope: An Invisible Worlds Window. *Ubicomp 2003*, 261-264. (2003)

4.Gu, Y., State, A. and Fuchs, H. A practical multi-viewer tabletop autostereoscopic display. *ISMAR 2010*, 147-156. (2010)

5.Kitamura, Y., Konishi, T., Yamamoto, S. and Kishino, F. Interactive stereoscopic display for three or more users. *SIGGRAPH 2001*, ACM: 231-240.(2001)

6.Wilson, A. D. TouchLight: an imaging touch screen and display for gesture-based interaction. *ICMI 2004*, ACM: 69-76.(2004)