Supporting Multiple Immersive Configurations Using a Shape-Changing Display

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Abstract

Immersive displays for virtual reality systems can be roughly classified into spatially immersive displays (similar to CAVE-like displays or large-screen simulators) or head-mounted displays. The former type is usually static in spatial configuration and configured to support a small group of users. The latter supports only a single user. We propose a new class of actuated, reconfigurable display that can support both small groups and individual users: in particular we suggest a robotic display that can change shape. The display can change shape to support different usage conditions, and can also move rapidly to give a larger apparent field of view for an individual user. We explore the potential advantages of a display that can move independently from its user(s), and we present a prototype that demonstrates some of the potential use scenarios.

Index Terms: H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality;

1 Introduction

One key aspect of virtual reality displays is that they surround the user to some extent. The surrounding nature of the display is usually achieved in one of two ways: either the displays are large and are placed around the user so that as the user turns one or more displays is visible, or a display with a large field of view is attached to the head of the user. Both approaches have their advantages and disadvantages. A head-mounted display (HMD) is necessarily a single user display because it is attached to the head. As the user's head moves the image must be updated very rapidly. Modern consumer HMDs achieve a latency of approximately 20ms but there will still be visual distortions. A further problem is that it is hard to achieve very high resolution and very high field of view. The types of physical display in a room that surround the user are sometimes collectively known as spatially immersive displays (SIDs) or "CAVE-like" displays, after the name of a well-known display of this type [3]. The advantage of a SID is that they can have higher resolution, higher field of view and support more than one user, but that this comes at considerable expense in terms of cost of displays and space. Another advantage of a SID is that the impact of latency in display generation is less noticeable: the images on the displays are mostly rotationally stable as the user turns their head.

In this paper, we explore the concept of a device that move and change shape in order to better support immersion. Visualisation of one concept for a shape-changing display is shown in Figure 1. This design essentially takes the concept of a single display wall and makes it a flexible sheet that can be controlled and deformed. In the first configuration the display forms a curved display a small group of users can stand around. In the second the display wraps around a single user.

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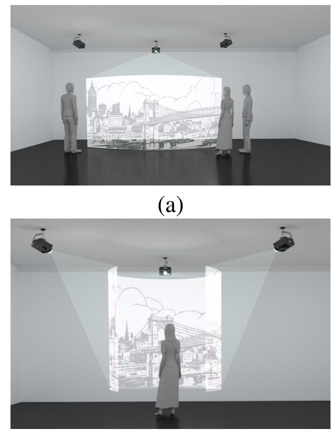


(a)

(b)

Figure 1: Visualisations of a concept for a shape-changing immersive display that can change to suit the number and placement of different users

This concept builds on a few recent themes in virtual reality and human-computer interaction research. These include the use of situated displays for specific collaboration or interaction scenarios such as the SphereAvatar, a spherical display [7] and TeleHuman, a cylindrical display [5]. A related area is projector camera systems, as exemplified by the Illumiroom concept [4]. Shape-changing displays have recently been explored for tangible and hand-held displays (e.g. [6]). At least one prototype consumer television product can change its curvature on command [2]. Our contribution is to take develop such concepts to support immersive displays and to explore some of the affordances that may become possible.

2 Implementation

A small prototype display has been built that demonstrates the main principles of the concept. The main components of the physical build were a flexible acrylic screen, two robot arms with six degree of freedom end controllers and a pair of projectors.

The screen is formed from a sheet of 3mm Perspex® *Opal 40* acrylic. The sheet is 0.6m by 0.85m, with 25mm on each shorter edge held within a bracket. The brackets to hold the vertical edges of the sheet were laser cut from 10mm white acrylic.

We had to control the flexible acrylic sheet to form a uniform curved surface for projection. Given the regular flexibility of the sheet and the ability to turn the brackets at any angle, we approximated the sheet as a vertical segment of a cylinder, and thus the profile could be analysed as the arc of a circle.

Two Kuka LBR IIWA 7 R800 robots were used to move the screen. These robots have 7 axes of rotational movement and a payload of 7kg. Their reach is approximately 1.2m. The two robots were aligned 0.88m apart when facing forwards.

The software used for programming the high-level robot control system was Kuka Sunrise Workbench 1.5. We used Kuka's Java API which provides various paradigms for controlling the robots.

Both robot controllers open non-blocking socket connections to a separate machine that acts as display controller.

The display controller is a Windows 8.1 program written in C# in Unity 5.1. The display controller is responsible for generating two video signals for the two projectors, interaction with the user and sending control messages to the high-level control system on both of the robot controllers. In this initial prototype the screen can be controllled to move smoothly between two positions.

Two projectors were used, see Figure 2. Projector A was an Optoma EH200ST Full HD (1920x1080p) DLP short-throw projector. Projector B was an Epson EB-585Wi WXGA, (1280 x 800) ultra-short-throw projector. Projector A is used when the screen is in the "in" position. Projector B is used when the screen is in the "out" position. Projector A is roughly aligned with the axis through the centre of the screen whereas Projector B sits roughly level with the bottom edge of the screen.

For both "in" and "out" screen positions, once images were rendered in Unity a vertical fish-eye correction was used to fit the image to the screen geometry. The parameters for these corrections were estimated by hand, by measuring the vertical extent of the projection in pixels in the middle and edge of the screens

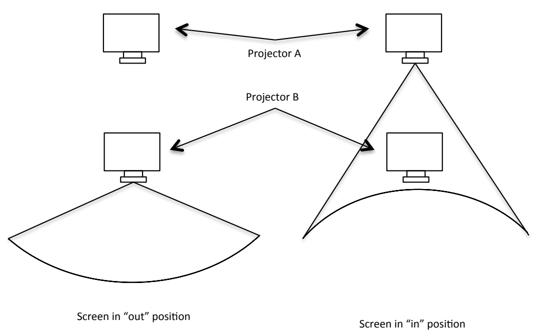


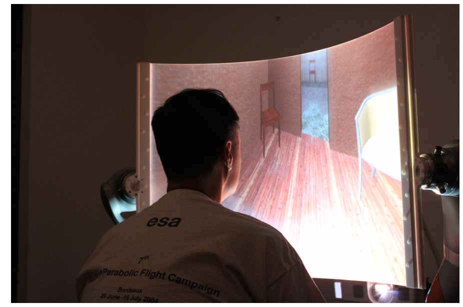
Figure 2: Projector configurations for the prototype implementation

The prototype display can be seen in Figure 3. In Figure 3a we can see a single user sat in front of the display, where it subtends a field of view of approximately 140° to the user. In Figure 3b we can see two users sat in front of the screen in the out position.

3 Conclusion

We have presented a new concept for a shape-changing immersive display system. For the single user, the display provides a highly immersive view without the need to wear a HMD. Because the panel can move, it can provide the appearance of a more surrounding environment than a large panel display or static curved display. In doing this it shares the advantages of SIDs over HMDs in that high frequency movement doesn't result in "swimming effects" of latency because the image and projection are stationary. Compared to a traditional SID, if the robotic display were stereo, being closer to the user would mean more incorrect parallax, but this can be planned for and compensated for in the screen control software: the screen could filter head position and attempt to manage the screen position to minimise latency effects. The display can be compared to previous devices such as the BOOM [1] which were movable but not shape-changing.

For a small group, the display provides a variety of viewing options. In this mode, the shape and position might be controlled both by the content and the user positions. For shared viewing of environment-like models, the users might prefer a wide field of view, whereas for an object-focussed task we might consider using



(a)

(b)

Figure 3: Users in front of the display. (a) Single user with the screen in "in" configuration. (b) Pair of users with the screen in the "out" configuration.

repeating projections on a cylindrical screen. Thus the display can support a variety of interaction modes.

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