Multiview User Interfaces with an Automultiscopic Display

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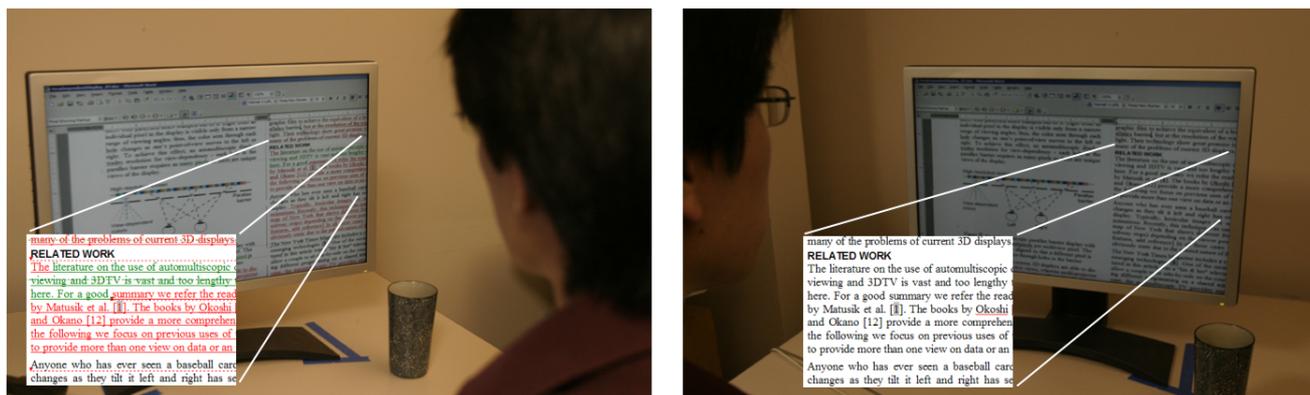**pfister@seas.harvard.edu**

Figure 1: A display that reveals both the marked-up (*left*) and final (*right*) versions of a document to different POVs.

ABSTRACT

Automultiscopic displays show 3D stereoscopic images that can be viewed from any viewpoint without special glasses. These displays are becoming widely available and affordable. In this paper, we describe how an automultiscopic display, built for viewing 3D images, can be repurposed to display 2D interfaces that appear differently from different points-of-view. For single-user applications, point-of-view becomes a means of input and a user is able to reveal different views of an application by simply moving their head left and right. For multi-user applications, a single-display application can show each member of the group a different variation of the interface. We outline three types of multi-view interfaces and illustrate each with example applications.

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces.

General terms: Design

Keywords: display, automultiscopic, multi-view

1. INTRODUCTION

Automultiscopic displays show 3D stereoscopic images that can be viewed by multiple people from many viewpoints without special glasses. These displays consist of an array of view-dependent pixels that reveal a different color to each eye of the user based on their point-of-view. View-dependent pixels can be implemented using conventional high-resolution displays and parallax-barriers (Figure 2). While the optical principles of multiview displays have been know for a century [6], only recently have high-resolution displays made them practical. Laptops with automultiscopic displays are commercially available [12], and (at the time of this writing) high-quality automultiscopic desktop monitors (such as the one shown in Figure 1) are available for around $3000 [10].

While automultiscopic displays are designed and built with the viewing of 3D images in mind, the properties of a multiview display create new and exciting opportunities for 2D user interfaces as well. If one thinks of a pixel's color as a function of not only its x and y coordinates, but also the point-of-view of the user, POV becomes a lightweight means of changing the appearance of the application. Where the color of a pixel is typically a function of its position on the screen, the color of a multiview pixel can be defined as:

$$pixelcolor_{x,y} = f(x, y, POV)$$

Figure 1 shows how the content of a graphical user interface changes as a function of point-of-view. In this example, the user of this view-dependent display is able to alter the appearance of the application by simply moving their head. Similarly, a group working in front of a view-dependent display can have separate views of the application.

The contribution of this paper is the outlining and illustration of several example view-dependent user interfaces using a commercial automultiscopic display. We group these examples into three groups based on the amount of continuity among views. We believe that these examples should aid the interested reader in their own exploration of multi-view user interfaces.

2. DEVICE DESCRIPTION

Commercial automultiscopic displays [7, 11] are based on parallax barriers or lenticular sheets placed on top of high resolution screens. Researchers have also used multi-projector systems [3, 8] to create these "glasses-free" 3D displays. Figure 2 shows a diagram of an automultiscopic display that reveals a different image to each eye of the user for the purpose of creating a 3D image. A high-resolution display is placed behind a parallax barrier – an opaque sheet with patterned holes stamped out of it. Light from an individual pixel in the display is visible only from a narrow range of viewing angles; thus, the color seen through each hole changes with changes to one's point-of-view.
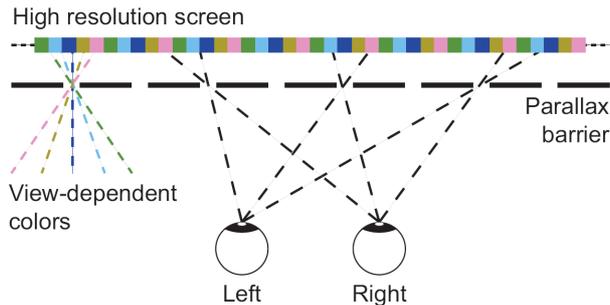

Figure 2: An automultiscopic parallax barrier display with five view-dependent subpixels per multiview pixel. The barrier and screen are aligned so that a different pixel is revealed to each eye through holes in the barrier.

Current commercial flat-screen 3D displays are able to display up to nine perspective views, whereas multi-projector 3D displays project 16 or more views. To project k views at m x n resolution requires an underlying image with km x n pixels. Vertical slits or lenses result in a k-fold loss in horizontal resolution. Slanting the slits or lenses at a small angle balances the loss of resolution in both directions. Parallax-barriers and lenticular sheets provide only horizontal parallax. Horizontal and vertical parallax is obtained using arrays of spherical lenses, or integral lens sheets. However, integral displays sacrifice significant spatial resolution in both dimensions to gain full parallax.

Important parameters of lenticular sheets and parallax-barriers are the number of lenticules (slits) per inch and the field-of-view (in degrees) of the viewing zone. The number of lenticules or slits corresponds to the effective multiview resolution of the display, i.e., the number of multiview pixels. The field of view of the display determines when the multiple views begin to repeat or "jump" back from view N to view 1. For example, on a display with 30 degrees field of view, a viewer moving their head toward the right will eventually move past 30 degrees, at which point, the image they see warps back to the image they would see if their head were 30 degrees back toward the left. While parallax-barriers reduce some of the brightness and sharpness of the image, lenticular sheets suffer from increased blurriness due to light diffusion inside the transparent sheet substrate. All multi-view displays suffer from crosstalk between views.

The company Holografika (http://www.holografika.com/) has developed a multiview display that uses a sheet of holographic film to achieve the equivalent of a lenticular or parallalax barrier, but at the resolution of the wavelength of light. Their technology show great promise to minimize many of the problems of current 3D displays.

3. RELATED WORK

The literature on the use of automultiscopic displays for 3D viewing and 3DTV is vast and too lengthy to be discussed here. For a good summary we refer the reader to the paper by Matusik et al. [8]. The books by Okoshi [9] and Javidi and Okano [2] provide a more comprehensive review. In the following we focus on previous uses of this technology to provide more than one view on data or an interface.

Anyone who has ever seen a baseball card whose image changes as they tilt it left and right has seen a lenticular display. Typically, lenticular images are used for simple animations. Recently, this technique was used to produce a map of New York that shows different features (such as subway stops) depending on the viewer position. In all these cases the images are obviously static due to the printed nature of the material.

The New York Times Magazine includes a yearly article on emerging technologies [5]. One of the recent projects featured in this article was a "his & her" television that would allow a couple to sit side-by-side on the couch while watching different programming on a shared television. This idea has recently been realized by Sharp Electronics, who have demonstrated a Triple Directional Viewing LCD capable of displaying different images to a driver, front seat, and back seat passengers. While similar to our solution, these multi-view displays are meant for multiple people and do not explore the use of multiple views for a single user.

Kakehi et al. [4] presented a view-dependent tabletop for group use. This system uses lumisty film and a Fresnel lens as a rear-projected tabletop with a separate projector for each user. These authors demonstrated several example applications, including a card game in which a player's cards were only visible to that player and were "face down" for other people standing around the display.

4. EXAMPLE APPLICATIONS

In this section, we describe several example applications that take advantage of a multi-view display. These examples use the users' point of view relative to the display as an input device; therefore, head movement becomes a lightweight means of getting different views of an interface.

While only a few examples are described in detail, we hope that these examples will allow the reader to recognize the value of multi-view interfaces for many types of applications. We organize these examples according to a *Continuity Among Views* and group them into the following areas:

1. Discrete Information
2. Layered, Registered Information
3. Continuous Variable Manipulation

Figure 3: (*top row*) A series of registered geospatial images displayed in different point of views. (*bottom row*) Different views show a continuous range of values in a high-dynamic range image.

4.1 Discrete views

In these examples, the views visible from different points-of-view contain discrete information. The effect is that the content of the screen changes completely as one moves their head into a different view region in front of the display.

Applications that allow the user to view data at multiple levels of magnification could benefit from a multi-view display that mapped different zoom levels to different points of view. For example, Figure 4 illustrates a system in which the area immediately around the mouse pointer is magnified and displayed in the far left and far right points of view. A user working with this application could simply move their head to the left or right to get a detailed view of the area of the display immediately around the mouse pointer. This would allow the user to make an accurate selection or perhaps just get a better view of a part of the display without mode switching into a zooming tool for what is a temporary change of magnification.
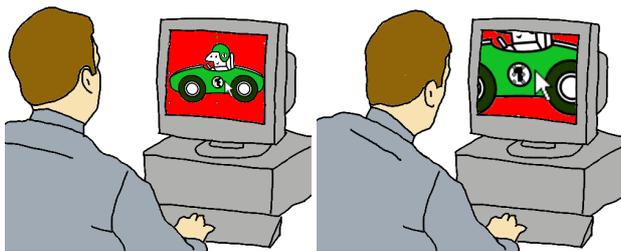

Figure 4: A magnified view around the mouse cursor is revealed from some points-of-view. A quick glimpse gives the user a detailed view without the need to switch tools.

Many applications could better support different uses of the same data by taking advantage of a multi-view display. For example, a multi-view enabled web browser could render a web page in the traditional manner in the primary point-of-view, and render the same web page in a summarized manner more appropriate for skimming in other points-of-view. A user searching through many pages could quickly skim pages by viewing them from one point-of-view and then switch to another point of view when a more detailed reading is desired.

4.2 Registered Layers of Information

The examples in this section take advantage of a multi-view display by showing different registered layers of information in each point of view. By allowing the user to control the layers of information by simply moving their head, their hands are free to continue performing input to control other facets of the application.

In our first example, we used a set of eight registered images showing different systems within the human body. The viewer is able to view different systems by moving their head left and right. The registration among images allows the viewer to see the relationship among the systems.

Our second example application uses layered geospatial information from Google Earth [1]. In this example, shown in Figure 3, different layers of information are visible from different points-of-view. All of the register images include a satellite photograph of a city, but different points of view augment this photograph with different layered information. From one view, the streets of the city are highlighted, from another the location of subway stations are visible, and so on. Were all of these layers of information made visible at the same time, the result would be a cluttered an unusable interface. By splitting these layers up into different view regions, we allow the user to switch between layers by simply moving their head left and right.

4.3 Mapping a Continuous Variable to Multiple Views

In these examples, we map a continuous variable to the user's view position. Any application with which the visualization can be controlled through the manipulation of a continuous variable should be able to take advantage of this method of control.

Our first example addresses a problem with high-dynamic range images: they contain more color information than can be properly displayed on a most displays. Applications built to view HDR images include GUI controls for manipulating the color range of interest. This range of interest is mapped to the visible range of the display, and portions of the image that fall above or below this range are clipped. We have mapped different ranges to different views on our automultiscopic display so that the viewer can inspect different color ranges by moving their head left and right in front of the display. An example set of ranges is shown in Figure 3.

Our second example addresses problems that arise when viewing 3D volumetric information on a 2D display. One solution is to render the information in the dataset in a semi-transparent manner so that distance parts are visible through close parts. Another solution is to give the user controls over a clipping plane that they can use to view 2D slices of the 3D dataset. We built an example volumetric data viewer that maps different 2D slices through the data to different points of view. The user of this example application changes the clipping plane by moving their head relative to the display.

Many applications attempt to balance the need to display lots of information with the desire to maintain an easily assessable, clutter free interface. Oftentimes, application developers allow the user to control the level of detail that is displayed in the application. We propose that multiple levels of detail can be displayed simultaneously on a multi-view display and that the user can choose the most appropriate level of detail by changing their point of view relative to the display.

5. MULTI-USER CONSIDERATIONS

Multi-view user interfaces have the potential to greatly impact the field of CSCW and single-display groupware. Kakehi et al. have enumerated many of the potential uses of a multi-view collaborative tabletop [4], and a repurposed automultiscopic display can provide many of the same benefits. For example, a single application could be modified to display labels, menus, and text in different languages in each view region of the display. Rather than specifically set a language preference, a user would simply position themselves in the region that matched their preferred language. Similarly, other appearance preferences, such as font size, could be mapped to viewing position. In a competitive gaming scenario, each group member could be given private information that was not visible to competitors.

6. CONCLUSION

The demand for 3D applications is bringing automultiscopic displays into the mainstream because of their ability to display 3D content without the need for special glasses. The increased availability of these displays is creating an opportunity for the repurposing of such displays to provide multi-view interfaces for 2D applications. We have presented the means of using an automultiscopic display for multi-view interfaces, and have illustrated a collection of example applications that take advantage of multiple views. It is our hope that these examples will convince the interested reader of the value of multi-view interfaces and of the relative ease with which they can be experimented with using commercial devices.

7. ACKNOWLEDGMENTS

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