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Perry Hoberman
Interactive Media Division
School of Cinematic Arts
University of Southern California
phoberman@cinema.usc.edu

Marientina Gotsis
Creative Media & Behavioral Health Center
Interactive Media Division
School of Cinematic Arts
University of Southern California
mgotsis@cinema.usc.edu

Andrew Sacher
Sacher Creative, Inc.
andrew@sachercreative.com

Mark Bolas
Interactive Media Division
School of Cinematic Arts
Mixed Reality Lab
Institute for Creative Technologies
University of Southern California
bolas@well.com

David Turpin
Interactive Media Division
School of Cinematic Arts
University of Southern California
dhturpin@gmail.com

Rohit Varma
Department of Ophthalmology
Keck School of Medicine
University of Southern California
rvarma@usc.edu

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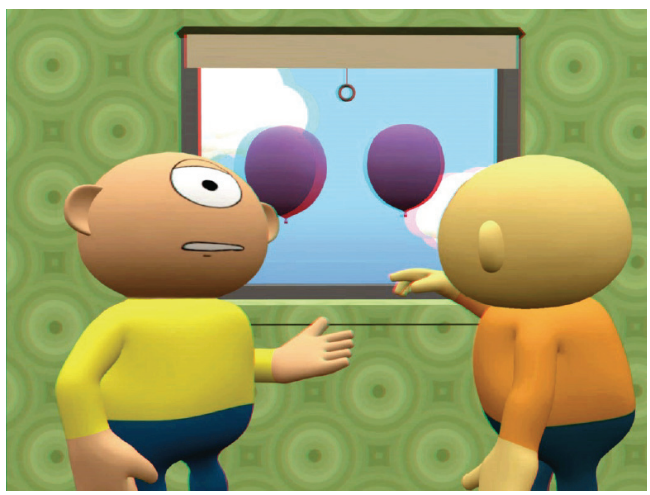

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Keywords-component; stereoscopy, computer graphics technique, mixed reality, display technology, experimental methods, collaborative interaction, 3D interaction, education, psychology, training, visualization, medicine, entertainment, virtual/digital characters, gesture, health promotion

I. Introduction

A team of research faculty and an independent game producer, working with students at the University of Southern California (USC) School of Cinematic Arts and Viterbi School of Engineering collaborated with a team at USC's Doheny Eye Institute to investigate the use of interactive media to increase participation in MEPEDS (Multi-Ethnic Pediatric Eye Disease Study), the first major epidemiological eye study of visual disorders in young children in the United States. The purpose of this collaboration was to develop a stereoscopic transmedia storytelling (STRANS) health promotion campaign for communicating the importance of healthy eyes in an entertaining, non-didactic manner, with a long-term goal of improving attitudes toward vision correction, as well as improving long-term follow-up with eye care providers. The STRANS campaign integrated with the epidemiological study procedures of recruitment and enrollment.

Currently, Dr. Rohit Varma, principal investigator of MEPEDS, Professor of Ophthalmology and Preventative Medicine and Director of the Glaucoma Service, Ocular Epidemiology Center and Clinical Trials Unit at the USC Keck School of Medicine mails a letter notifying potential participants that study coordinators will be in their neighborhood. Potential participants are subsequently visited to determine eligibility, consented in the home and scheduled for a comprehensive eye examination at the study clinic, or the mobile clinic. Although free, the eye exam is time-consuming (three hours). On average, 10% of children need a referral for vision problems, such as astigmatism, strabismus and amblyopia [1-3]. Strabismus has been

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associated with significantly decreased quality of life in children [3]. MEPEDS provides referrals for children who require correction or treatment. The families are visited a few years later to track changes in vision acuity.

Discussions between Dr. Varma, his team and the research faculty at the Interactive Media Division of the School of Cinematic Arts revealed an opportunity to increase commitment and participation in MEPEDS by creating and disseminating entertaining visual materials at various steps of the study process. We mutually agreed to center materials around the subject of vision and visual perception since encouraging positive attitudes about healthy vision and vision correction would be most likely to serve overall goal of greater participation and follow-up.

The subject of binocular vision (stereoscopic 3D) was chosen, in part because of the current surge of interest in stereo 3D, but also because low stereo acuity in children naturally alters how they perceive the world [4]. We felt that recent fascination with stereo 3D could lead to a desire to learn something about how stereoscopic vision actually works. Our team attempted to develop an approach that could: (a) increase community awareness of the study, (b) foster positives attitudes about the study, (c) create a positive emotional experience at the clinic, (d) explore the potential of STRANS for health education. These potential outcomes will be evaluated in a future study.

The project was structured as a three-phase transmedia narrative, built around a pair of one-eyed (cyclopean) cartoon characters named *Lefty* and *Righty*, with the concept being that the two of them could only see in stereoscopic 3D if they cooperated and collaborated with each other. Each phase was designed to bring an increased a sense of involvement, moving from print media to digital video, and finally to an interactive experience.

Figure 1. MEPEDS 3D comic strip

The first phase took the form of a 3D comic strip, printed using an anaglyph (red/cyan) process, included with the initial preliminary letter soliciting participation in the study (Fig. 1). This was followed by a stereo 3D animation (with the same characters), to be displayed in anaglyph on the screener's laptop during site visits (Fig. 2), as well as in full-color polarized 3D on a flat screen in the waiting room of the clinic. As of recently, YouTube supports 3D stereo and the animations have been posted online.

The third phase of the project culminated in a two-person multitouch game deployed on the Microsoft Surface installed in the research clinic's waiting room area. This paper details the conceptual and technical challenges related to development of the tabletop game.

II. Background

Perspectival anamorphosis utilizes the perspective projection of an image onto a surface at an oblique angle to the projection itself, thereby requiring the image to be viewed from a specific vantage point. One of its traditional uses in art has been as a means of hiding an image from immediate apprehension (as in the painter Hans Holbein's *The Ambassadors*, where a distorted view of a skull initially appears as a ghostly wraith, only becoming coherent when seen from an acute angle).

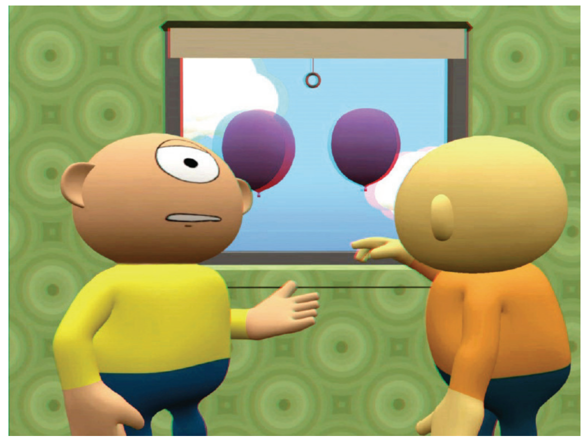

Figure 2. MEPEDS 3D animation still

Anamorphosis can also be used as a means of enhancing the spatial realism of an image by emphasizing a single ideal vantage point from which to view the image; as such, it is part of the arsenal of *trompe l'oeil* effects employed by various artists for centuries. In a certain sense, all normal perspective projection can be seen as a special case of anamorphic projection, in which the projection surface is at right angles to the line of sight; and in fact, all perspectival images also posit their own ideal vantage point (usually a center point directly in front of the image).

A *phantogram* is a stereoscopic anamorphic image, generally made to be viewed on a horizontal surface such as a tabletop from an angle of approximately 45 degrees [5]. By exploiting the conjunction of the (actual) flat tabletop with its (virtual) representation in the stereoscopic image, objects can be made to convincingly 'pop up' from the tabletop with surprising realism, even when displayed as anaglyphs (red/blue filtered images).

A phantogram can thus be seen as a special case of the viewer-centric perspective required by the CAVE™ (Cave Automatic Virtual Environment) [6] and similar projection-based head-tracked virtual reality configurations. In fact, this type of viewer-centric projection is precisely the real-time calculation of anamorphic projection, updated continuously through the use of head-tracking. Like any projection-based viewer-centric display, phantogram views are generated with an off-axis frustum, in which the line of sight is at some oblique angle to the projection surface. These displays are also instances of *orthostereoscopic* imaging, in which the position and optics of the virtual cameras are modeled as precisely as possible to the viewer's position and gaze.

Lacking the head tracking and immersive qualities of a CAVE™ (as well as some recent tabletop projects; see [7]), the phantogram might be seen as a rather primitive and limited media form, especially in its usual presentation as fixed anaglyph image. However, it exhibits some subtle qualities that enhance its effectiveness, in spite of its limitations.

By using a horizontal rather than an upright projection surface, the phantogram emphasizes the weight and solidity of virtual objects; rather than floating in space, or resting on equally virtual surfaces, the objects in a phantogram seem to sit on the actual surface of the tabletop. And because the boundary of the image is congruent with the tabletop, the virtual objects can be seen in same context as the table itself, giving them added status as objects in the world. For these reasons, phantograms could be called a form of *proto-augmented reality*, in which virtual objects are apprehended as, and registered to, the physical environment.

Although any particular phantogram has to be generated to correspond to a single defined vantage point, there is generally a zone around this point from which the phantogram can still be viewed, albeit with some amount of distortion depending on the direction (a skew from any horizontal offset, and a compression/extension resulting from varying distance). This distortion is immediately apparent with a change of position, but to a large extent the visual system adapts to the new vantage point over a short period (just as we adapt to off-axis viewing angles in movie theatres), and thus images can be viewed convincingly by several viewers at once (just as a CAVE can be viewed from a number of angles nearby the head-tracked position), even without head-tracking.

The *Microsoft Surface* is a table-sized multi-touch, multi-user platform that uses a built-in rear-projection system to display a 1024 x 768 image on a 30" horizontal screen surface. Designed to withstand harsh environments (such as museums, restaurants and bars), the Surface is fairly rugged, and is thus an appropriate choice for the deployment of an interactive game in a public setting for young children. The expected traffic at the MEPEDS clinic may be as high as 40 families per week. The tabletop is 27 inches off the ground, making it an ideal height for small children seated in appropriately-sized chairs or stools. Using a five camera vision system and a near-infrared light source, the Surface is able to track up to 52 simultaneous touches at a resolution of 48 dots per inch.

III. CONCEPT DESIGN

In designing a framework for the game prototype, the team had a number of specific requirements that needed to be coordinated and reconciled. Because the game was going to be played primarily by children under the age of six and their caretakers, we decided to design a simple, casual, non-competitive game for two [8]. Although the Microsoft Surface is designed to accommodate users seated anywhere around the unit, we decided against having the two players face each other across the table, since we wanted to make an experience that would encourage collaboration and cooperation [9]. This also fit well with the requirements for a phantogram, which has fairly stringent requirements for viewing position. The Surface is a self-contained unit with a fixed, non-stereo ready projector, so we employed anaglyph stereo rendering (with red /cyan images).

Although it is possible to treat the projection surface of a phantogram as a window on a virtual world (just like a normal upright screen), it is most effective when the ground plane is matched with the screen surface, which results in all other virtual objects being placed stereoscopically in front of that surface. In other words, every object other than the ground plane has negative parallax (where the left eye image appears to the right of the right eye image). Because the stereoscopic illusion breaks down when objects having negative parallax are clipped by the projection edge (since they cannot be simultaneously in front of and in back of the screen edge), it is preferable, if not necessary, to keep objects contained entirely within the projected area.

Figure 3. *Lefty* at 'home' on the Microsoft Surface

Because a phantogram depends on the confluence of the physical and the virtual to create its effect, and because it is a form of near-field (within arm's length) stereography, the scale of virtual objects is perceived to not be the result of the optics of a particular camera, but as the actual size of their presentation. We therefore decided to treat the table surface as a miniature toy-sized world seen by from a fixed vantage point, with the characters appearing to be only a few inches in height. This was in keeping in with the game's target audience of young children.

The game design team developed and presented a number of scenarios, most of which foregrounded the pleasure and utility of stereoscopic vision. These were playtested with the team internally and informally tested with kids ages 3-6 at the clinic. Two scenarios were developed, one indoor and one outdoor. In the indoor scenario, the characters are inside their home, with all furnishings appearing as two-dimensional pictures scattered on the floor. When both characters stand side-by-side in front of one of these pictures, (thus creating the condition for binocular vision) the picture is suddenly pumped up (like a balloon) into a full three dimensional object that can then be utilized by the characters (Fig. 3). Coaxing the characters to come together so the objects would become fully dimensional was deemed conceptually advanced for the age we were targeting, therefore development of this version was placed on hold in favor of a simpler outdoor scenario. The outdoor scenario takes place in an idyllic garden setting, with *Lefty* and *Righty* each exploring their environment with a large magnifying glass (about the size of the characters' heads).. Sprinkled throughout the garden are a variety of miniature creatures. When users manipulate *Lefty* or *Righty* to view one of these creatures through their magnifying glasses, the creatures pop into full size and detail and appear "enchanted" for a few seconds, illustrating how lenses and optical devices can aid and correct vision in a non-didactic way.

Two users can simultaneously steer the characters to pursue small crawling and flying creatures that populate the garden. When one of the characters catches up with one of the creatures, that character raises his magnifying glass, thereby 'magnifying' the creature, which suddenly pops up scale and detail (Fig. 4). The characters demonstrate joy through their affect when they magnify and thus 'enchant' creatures. A sign post keeps track of time and collects 'badges' representing each creature found. If the characters find all the creatures within the given time limit, they do a little dance together and the game fades away and restarts. If time runs out, the game fades and restarts with the characters in new locations looking for creatures.

Although brief, the experience can be repeated a few times as children learn how to navigate and with an estimated depth of play under 3 minutes and length of engagement between 5-8 minutes. The success of these metrics remains to be tested, but informal testing showed optimal performance within this range by 4-6 year olds.

IV. Software Implementation

Once we decided on the garden scenario, assets were developed in Maya, including fully rigged versions of *Lefty* and *Righty*, with textures created in Photoshop and other programs. We developed the application using the Unity 3D engine, which is well-supported and capable of displaying stereoscopic images. Unity is cross-platform, and day-to-day development took place mostly on the MacOS side. A custom script was developed to handle the off-axis projection (using the Camera Class projectionMatrix variable) and the generation of left-right anaglyph images (using Render Textures), as well a script for communicating with a concurrently-running application that processed Surface touch events.

We discovered a Unity engine bug that disabled Render Textures when using an off-axis frustum, making it impossible to generate and display an anaglyph phantogram image simultaneously. A workaround was found by using a stereoscopic driver available from iZ3D; this freed up Unity to render the views directly to a window (instead of a Render Texture), with iZ3D handling the task of combining the left and right views into a single anaglyph image.

V. Interaction Design

In the process of attempting to find an intuitive and straightforward method for controlling the characters, we experimented with a number of different interaction models. Objects placed above the tabletop (with negative parallax) present a real challenge for touch-based interaction, since touch is by definition restricted to the two-dimensional tabletop, making periodic occlusion of the objects by the user's hand almost inevitable. This momentarily destroys the stereoscopic illusion.

We considered treating the table surface as a transparent ceiling, with the garden scene and characters placed below it (with positive parallax), but it was found that this largely removed any sense that the space of the game was contiguous with our own world. Eventually we accepted the inevitability of these occlusions, and instead focused on methods for minimizing their occurrence and duration. Therefore, actions that required the user to continuously touch the character (such as pushing or grabbing) were rejected, in favor of actions that encouraged users to touch the flat ground plane instead.

Figure 4. *Lefty* and *Righty* in the garden

At the other extreme, the most 'hands off' method involved dragging a finger along the ground to set a path for the character to follow, but this was felt to be too indirect, analogous to dropping a trail of breadcrumbs for the characters to follow. We also did not want players to become preoccupied with drawing patterns on the surface, thus confusing the game objective.

The most intuitive control seemed to be somewhere in between, in effect pointing or dragging along the desired location, with the character following close behind. We found that occlusions could be minimized by introducing a slight lag to the character's response, which usually resulted in a bit of distance between the character and the user's hand, while maintaining a sense of close control. Instead of placing an absolute limit on how close a touch had to be to initiate a character's movement, we implemented a limit for how far or fast the character could move; in effect, this meant that a distant touch would only bring the character partway to the desired destination, with the almost universal response being to next touch an intermediate point to coax the character closer. Since there was no foolproof way to tell which player initiated any particular touch, we relied on proximity to the characters and to previous touches, ignoring any touches that were equidistant from both characters.

Each touch (whether effective or not) triggered a subtle sparkling particle effect at the location of the touch, accompanied by a sound effect, which provided instant and perceptible feedback for every interaction. A fairly quiet ambient soundtrack of natural sounds, as well as appropriate sound effects triggered upon the appearance of each creature, enhanced user involvement as well.

VI. Future Directions

We have conducted informal assessment of the game's conceptual effectiveness and technical robustness by observing its use on site in the MEPEDS clinic in Alhambra with custom-sized anaglyph glasses for children (Fig. 5). We plan to conduct a formal on-site usability/playability evaluation, revise the garden game and then implement and test the indoor scenario. Ultimately, the game and the STRANS campaign as a whole has to be tested within the MEPEDS study. There was anecdotal evidence that children who played the game may be better equipped to be tested with the current standard instrument for stereo acuity in children. We are pursuing a potential study design that could test this hypothesis.

Figure 5. Children playing the game at the MEPEDS clinic

Our experience taught us that the use of anaglyph display severely restricted the color and visual style of the project, and we are anxious to move beyond its limits. Available full-color stereoscopic display technologies include field-sequential (requiring active shutter glasses), micro-polarizer (with passive polarizing glasses), and lenticular (autostereoscopic) displays. The target audience of small children precludes the use of active shutter glasses, but passive glasses would be acceptable. Autostereoscopic displays have limited viewing zones, but obviously a glasses-free solution would be attractive.

A camera-based system for either head-tracking and/or "in the air" three-dimensional interaction (as in some other recent projects; see [10] is also under consideration, but we should emphasize that we were pleasantly surprised at how effective the technique of fixed stereoscopic anamorphosis was in creating a convincing augmented reality experience.

Acknowledgments

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