VizSpace: Interaction in the Positive Parallax Screen Plane

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Abstract

The VizSpace is a physically situated interactive system that combines touch and hand interactions behind the screen to create the effect that users are reaching inside and interacting in a 3D virtual workspace. It extends the conventional touch table interface with hand tracking and 3D visualization to enable interaction in the positive parallax plane, where the binocular focus falls behind the screen so as not to occlude projected images. This paper covers the system design, human factors and ergonomics considerations for an interactive and immersive gesture-based visualization system. Results are presented from a preliminary user study that validates the usability of VizSpace.

Index Terms: H.5.2 [Information Interfaces and Presentation (e.g. HCI)]: User Interfaces - Interaction Styles—

1 Introduction

Objects in 3D stereoscopic scenes can be behind or inside the screen (positive parallax), on the screen plane (zero parallax), or outside the screen (negative parallax)[5]. Usually, interaction with and visualization of a 3D environment are decoupled [5] because manipulation of stereoscopic content tends to take place in a different plane (usually zero or negative parallax) than the viewing plane where the objects of interest are placed. Objects placed at zero parallax work well with 2D touch interaction but do not work as well for objects that appear in front of or behind the screen [2]. As such, this paper presents a concept that aims to create unique and fluid interactions that combine hand gestures with touch in the positive parallax plane, i.e. between the surface of the multitouch table and the projection screen. The concept of interacting behind (or in our case, underneath) the screen has previously been demonstrated in SpaceTop [4] and Holodesk [3]. This research extends previous work by building a system that combines hand and touch interaction in an interactive collaborative space that can potentially support multiple users without occluding projected content.

2 Implementation

The VizSpace hardware setup (Figure 1(a)) includes three components: a multitouch table for multiple touch inputs; a 3D stereoscopic projector for visualization; and a Leap Motion controller for hand tracking. We designed a frame around and over the touch table to mount the projection screen and leap motion controller. Users place their hands in between the projection screen and the top of the touch table to interact with the applications whilst visualizing the application on the projection screen (Figure 1(b)).

2.1 Frame Design

The design of the frame brings together the three components of the VizSpace for a seamless experience. The frame's adjustable upper half allows the VizSpace to be customized to any height, while also providing several mounting positions for the hand tracking controller to be adjusted/relocated depending on the application. A projection screen is mounted on top of the frame, receiving the images projected by the 3D stereoscopic short-throw projector that is attached to the ceiling. The frame was designed in a 3D CAD Design software (Solidworks) and manufactured using a T-slot aluminum framing system.

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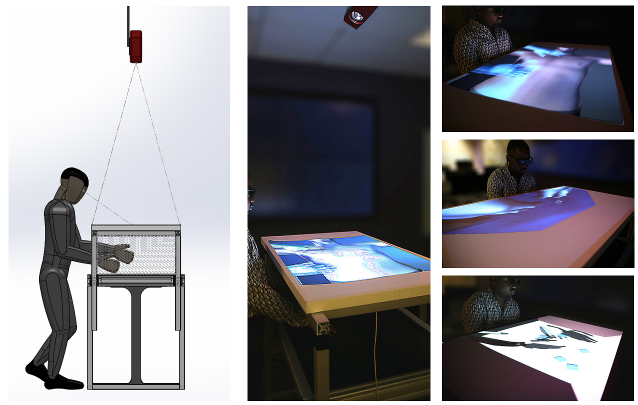

(a) (b) (c)

Figure 1: VizSpace Setup, Illustration and Applications

2.2 Multitouch table and Integrated Computer System

Touch interaction is achieved using a Platform 46 multitouch table. It has a 1080p HD LCD display panel and an integrated computer system (Intel i7 3.1GHz processor, 2GB Nvidia Graphics and 16GB RAM). The table is 34 inches high. We turned off the multitouch table's display and duplicated it through the 3D stereoscopic projector via the HDMI interface. The surface of the multitouch table also serves as a touch point of reference, which enables touch feedback, such as picking up a virtual object placed on a virtual floor surface or touching the surface of an object.

2.3 3D Stereoscopic Projection

We used the Acer Predator Z650 projector with HD (1920×1080) resolution and short-throw projection (100" at 1.5m). The Digital Light Processing (DLP) 3D projector use the built-in DLP LINK technology to synchronize the active shutter glasses with the display. Users wear the glasses to visualize the applications in 3D stereoscopic mode. Stereo convergence is set to be in front of the 3D scene (objects of interest) within the 3D applications to achieve a positive parallax effect and enable users to see beneath the projection screen (as opposed to a 'pop-out' effect).

2.4 Interaction Space

Touch and hand gesture tracking occurs in the interaction space or volume. We used the Leap Motion sensor to track users' hand and finger movements in 3D space. The sensor was mounted under the projection screen facing downwards and centered over the multitouch table. The Leap Motion Controller's field of view (FOV) is 150 degrees wide and 120 degrees deep (averaging 135 degrees). The height of the sensor, relative to the touch surface, is set by the vertical position of the frame. The sensor uses two cameras and three infrared LEDs to capture images of the hands and fingers before performing computer vision algorithms on the resulting images. The images are analyzed to reconstruct a 3D representation of what the sensor sees. As users interact with the system, they are able to see a 3D model of their hands within the 3D applications.

The placement of the projection screen and the Leap Motion sensor is determined by two major factors: (i) the needs of the 3D applications and (ii) the height of the user. For example, an air hockey application requires the user to be at one of the shorter ends of the multitouch table. In this case, placement of the sensor would be off-center, as the reach of the user would be limited. Additionally, taller participants will need the projection screen adjusted to a higher height. The adjustable frame design of the VizSpace was constructed to be flexible and adaptable to users' needs. However, our preliminary user study was limited to a fixed height of 12 inches above the multitouch table. In our applications, we matched the physical placement of the sensor within the interaction space to the virtual position and orientation within the 3D applications. The Leap Motion controllers' coordinate system was used, with the table surface mapped to the z-plane.

2.5 3D Applications

- Human Body Application: This application (Figure 1(c)) enables the user to identify functions of the human body via touch and sound. When a user touches a point on the patient, a sound representative of an associated function plays. Currently, sounds play from the nose, mouth, heart, lungs, and intestines. The surface of the touch table is matched to the body surface of the patient/avatar.
- Cube Wave Application: This application (Figure 1(c)) enables the user to visualize sound. When the user moves their hand in the interaction space, blocks are activated in a wave-like motion. Sounds, similar to a piano effect, are audible when the user touches the table. The pitch will change depending on where the user presses on the table. This allows the user to visualize a representation of their hands and the sounds produced, whilst getting touch feedback from pressing on the touch table.
- Blocks Sandbox Application: This application (Figure 1(c)) allows the user to interact with blocks by grabbing them within a room designed to match the tracking volume of the Leap motion. The floor space matches the touch surface of the table, giving users some touch feedback when picking up blocks. Mid air interaction occurs when users hold the virtual blocks.

3 Preliminary User Evaluation

We conducted a user study to evaluate the system's usability. The study consisted of 12 participants (6 males and 6 females). Their ages ranged from 21 to 53 with an average age of 28.8 and a median of 23.5. Heights were collected in 6-inch aggregates from *Under 5'* to *Above 6'5"*. Participants' height ranges were: 5' - 5'5" (two); 5'6" - 5'11" (six); 6' - 6'5" (two); above 6'5" (one). One participant did not provide this optional data. All participants were students or employees of Clemson University. Each participant was provided with a brief scripted orientation by the researcher, who explained the fundamentals of the VizSpace and its functions. The researcher then provided a scripted and limited description of each of the applications. These descriptions stated the applications' objectives and how to manipulate the contents.

Using a counterbalanced measures design, we mixed the three applications in order to reduce any confounding influence of the orderings such as learning effects or fatigue. The researcher then launched each application and directed the participant to explore the interactions within each application. The participant was given up to 5 minutes to experience each application. This process was repeated for the other two applications based on the participant's assigned ordering. We did not adjust the height of the frame for this study. The volume of the interaction space was fixed at $42 \times 25 \times 12$ inches for our preliminary user study. At the end of the study, participants completed the System Usability Scale (SUS) [1], a simple, ten-item Likert scale giving a global view of subjective assessments of usability.

The SUS score was 71 (a score of 70 and over indicates promising acceptability in the field). The responses (5-point Likert scale) indicated that participants did not find the VizSpace system unnecessarily complex, thought that the system was easy to use, found the various functions in this system were well integrated and would imagine that most people would learn to use this system very quickly. One participant specifically commented that the system "*had a very quick learning curve...within the first minute, I felt confident in using the system (where my hands should be, what I could do)*". The participant who was above 6'5" commented that "*height adjustment would be nice*". We intend to address system consistency and height adjustment in future, which were not fully addressed due to our rapid prototyping and explorative approach.

4 Conclusions and Future Work

VizSpace is an interactive visualization system that has been designed to combine touch and hand tracking technologies with a 3D experience in the positive parallax plane, allowing a user to simulate reaching inside and interacting with an object inside of a 3D virtual workspace. The Leap Motion controller's hand tracking technology is used to extend the conventional touch table interface into a 3D projected workspace, enabling an intuitive and advanced interaction technique. Results of the usability study led to the conclusion that the VizSpace is easy to learn, use, and understand.

VizSpace can be advanced further. We specifically want to evaluate VizSpace's ergonomics, collaborative capabilities, and visualization applications. We plan to improve ergonomics and general usability with careful updates to the physical set-up. For instance, we will be evaluating the use of a height-adjustable ergonomic standing stool to account for users of varying heights. Additionally, VizSpace has the potential to provide a collaborative workspace if multiple Leap motion controllers can be integrated together. This will enable utility of the multitouch functionality. We also intend to integrate head tracking so that applications are presented in the correct perspective to the user in single-user mode. Finally, future applications for VizSpace will include design for collaborative applications such as scientific visualization and medical training, leading to practical and detailed opportunities for STEM education and training.

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