Pinch-the-Sky Dome: Freehand Multi-Point Interactions with Immersive Omni-Directional Data

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Abstract
Pinch-the-Sky Dome is a large immersive installation where several users can interact simultaneously with omni-directional data inside of a tilted geodesic dome. Our system consists of an omni-directional projector-camera unit in the center of the dome. The projector is able to project an image spanning the entire 360 degrees and a camera is used to track freehand gestures for navigation of the content. The interactive demos include: 1) the exploration of the astronomical data provided by World Wide Telescope, 2) social networking 3D graph visualizations, 3) immersive panoramic images, and 4) 360 degree video conferencing. We combine speech commands with freehand pinch gestures to provide a highly immersive and interactive experience to several users inside the dome, with a very wide field of view for each user.

Keywords
Freehand interaction, omni-directional interface, gestures, dome, curved displays.

ACM Classification Keywords

H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces – Input devices and strategies: Graphical user interfaces.

General Terms

Design, Human Factors.

Introduction

Pinch-the-Sky Dome is a large immersive installation where several users can interact simultaneously with omni-directional data inside of a tilted geodesic dome (Figure 1). This experience is designed to immerse the users in the omni-directional visualization and allow them to manipulate and interact with data using freehand gestures in mid-air without the need to wear or hold tracking devices. In designing this experience, we focused on exploring ways to allow the users to interact with immersive content beyond arm's reach through simple gestures and without on-body trackers. We also aimed to highlight the increasing availability of omni-directional content (e.g., panoramic imagery, space data, earth mapping data, etc.) and explore effective ways of visualizing it within an immersive curved display.

Dome Experience

The user enters the dome through the entry gate which is designed to capture outside light. Inside, the user is immersed in a 360 degree interactive experience. Our 9ft (2.7m) dome can comfortably accommodate up to 5 observers at any given time. Inside, the observers have a choice of four different visualizations.

Figure 1. Pinch-the-Sky Dome (the entry gate is not shown in order to capture the user inside).

First, we project astronomical imagery from World Wide Telescope[1] in our dome and allow the user to explore the sky and the universe by simply moving their hands above the projector (Figure 2a). As part of the experience, the users travel around the Solar system, visit the outskirts of the known universe, and observe the incredible imagery from the Hubble Space Telescope.

Second, the observers can be virtually transported to several remote destinations by presenting high resolution omni-directional panoramic images; for example, Apollo 12 lunar landing site, the lobby of the Microsoft Research building, etc. (Figure 2b).

Third, we show a live feed from a 360 degree camera which can be used for omni-directional video

[1] http://www.worldwidetelescope.org

conferencing scenarios with remote participants (Figure 2c).

Lastly, the observers can explore complex custom made 3D graph visualizations (Figure 2d) showing the social network graph of one of the authors or animations that highlight the immersive nature of the dome.

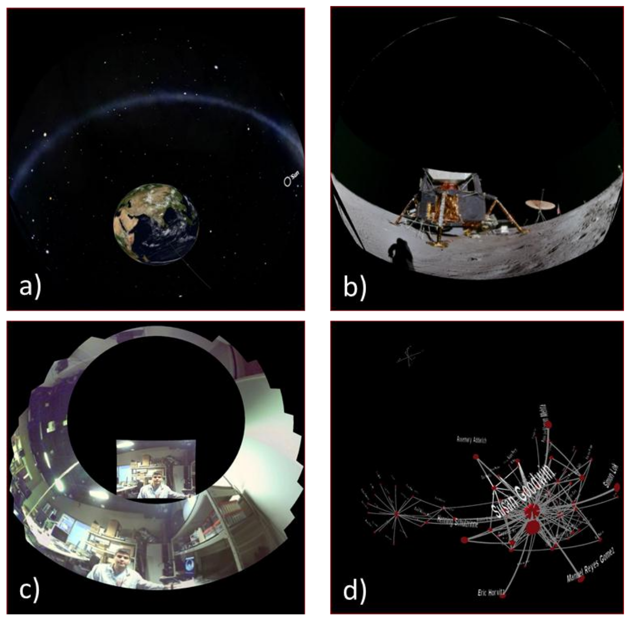

Figure 2. A collection of four different applications shown in the dome: a) World Wide Telescope (e.g., Solar System visualization), b) panoramic imagery (e.g., the Apollo 17 lunar landing site), c) 360 degree video-conferencing application, and d) 3D visualization of a social networking graph. Note: images are circularly distorted for dome projection.

Implementation

Our 9ft geodesic dome is constructed of cardboard sheets following a 2V design[2], using large paper clips to hold the cardboard sheets together. The dome rests on a 30 degree tilted base built of standard construction lumber. We wrapped base area under the dome with dark fabric to ensure light insulation. The cardboard dome surrounds the projector and serves as the large hemispherical projection surface. The various elements of this construction can be seen in Figure 1.

Figure 3. The projector-camera unit with a wide angle lens and the infrared illumination ring around it.

In the middle of the dome, we placed a custom-made omni-directional projector-camera unit (Figure 3). This unit is based on the Magic Planet display from Global Imagination, Inc[3] which we previously

[2] http://www.desertdomes.com

[3] http://www.globalimagination.com

demonstrated in our Sphere project [2]. The Magic Planet projector base uses a high-resolution DLP projector (Projection Design F20 sx+, 1400x1050 pixels) and a custom wide-angle lens to project imagery from the bottom of the device onto a spherical surface. In this project, we removed the spherical display surface of Magic Planet and simply projected onto the entire hemisphere of the dome surface. The quality of the projected image depends on the size of the dome; the brightness, contrast, and resolution of the projector; and the amount of ambient light that enters the dome. Our projector is capable of displaying a circular image with diameter of 1050 pixels, or approximately 866,000 pixels.

To enable freehand interactions above the projector in mid-air, we reused the same optical axis of the projection and we added: an infra-red (IR) sensitive camera, an IR-pass filter for the camera, an IR-cut filter for the projector, an IR illumination ring, and a cold mirror. The physical layout of these components is illustrated in Figure 4.

Gesture-sensing is performed by an IR camera (Firefly MV camera by Point Grey Research[4]). This camera is able to image the entire area of the projected display. To ensure that sensing is not affected by currently visible projected data, we perform touch-sensing in the IR portion of the light spectrum, while the projected display contains only light in the visible spectrum. This light spectrum separation approach has previously been demonstrated in many camera-based sensing prototypes. To provide IR light used in sensing, our setup requires a separate IR illumination source (i.e., the illumination ring around the lens).

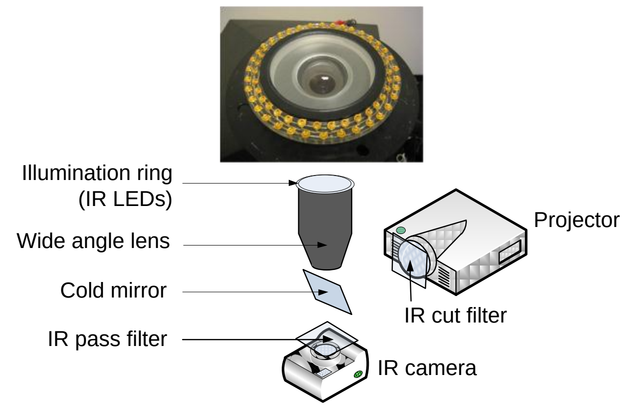

Figure 4. Schematic of the omni-directional projector-camera unit. The detail image shows the wide-angle lens and the IR illumination ring around it.

User Interactions

The main contribution of this work is in enabling the user to interact with omni-directional data in the dome using simple freehand gestures above the projector without special gloves or tracking devices. We acknowledge that for many scenarios there are important benefits associated with using tracked physical devices; for example, reduction of hand movement and fatigue, availability of mode-switching buttons, and haptic feedback. On the other hand, tracked devices can be cumbersome, may be prone to getting lost, require batteries, and so on. Furthermore, in multi-user collaborative scenarios, the need to hand off a tracked device in order to be able to interact with

[4] http://www.ptgrey.com

the system can impede the flexibility and the fluidity of interaction.

One crucial freehand gestural interaction issue is the problem of *gesture delimiters*, i.e., how can the system know when the movement is supposed to be a particular gesture or action and not simply a natural human movement through space. For surface interactions, touch contacts provide straightforward delimiters: when the user touches the surface they are engaged/interacting, and lift off usually signals the end of the action. However in mid-air, it is not often obvious how to disengage from the 3D environment we live in. This issue is similar to the classical *Midas touch* problem. Therefore, gestures should be designed to avoid accidental activation, but remain simple and easy to perform and detect.

Since our projector-aligned camera is able to image the entire dome, it is difficult to detect when the user is actively engaged with the system and when they are simply watching or interacting with others in the dome. We require a simple and reliable way to detect when the interactions begin and end (i.e., the equivalent of a mouse click in a standard user interface). We therefore chose the *pinching gesture* (from [5]) as the basic unit of interaction. This can be seen by the camera as two fingers of the hand coming together and making a small hole (Figure 5). This enabled us to literally pinch the content and move it around to follow the hand, or introduce two or more pinches to zoom in or out similar to more standard multi-touch interactions available on interactive surfaces.

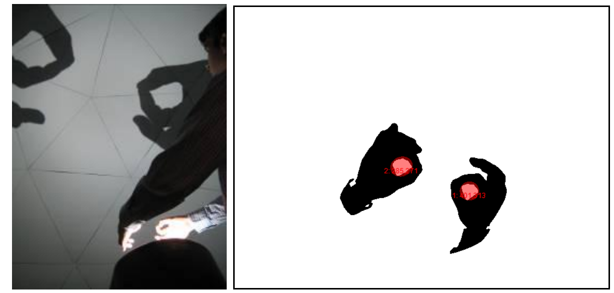

Figure 5. The detection of pinching gestures above the projector (left) in our binarized camera image (right). Red ellipses mark the points where pinching was detected.

Figure 6. Using a pinching gesture to interact with the projected content. The user is also wearing a headset microphone.

We extended this basic functionality with speech recognition in combination with a specific hand gesture: the user may put two hands together (making in effect a larger pinch or hole) and then speak a verbal command which in turn switches visualization modes.

Conclusions and Future Work

Pinch-the-Sky Dome showcases how simple gestural interactions can greatly enhance the immersive experience and how large wide-field-of-view displays provide an immersive perspective of standard widely available data. The inspiration for our work comes from the early work of Wellner [4] and Pinhanez et al. [3] where they imagined many interactive surfaces in the environment adapting to the users and their context. While Pinhanez et al. [3] explored similar ideas while researching interactions with a steerable projector, they were unable to simultaneously project on a variety of surfaces in the environment, which we are able to do. However, the limited brightness and resolution of today's projectors prevents us from fully realizing this vision without an enclosed and perfectly dark room.

Ultimately, we would like to simply place our projector-camera setup in any room and use any surface (walls, tables, couches, etc.) for both projection and interaction, making the idea of on-demand ubiquitous interactive surfaces a reality.

Acknowledgements

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