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A Low-Latency, High-Precision Handheld Perspective Corrected Display

François Bérard* Université Grenoble Alpes
Thibault Louis† Université Grenoble Alpes

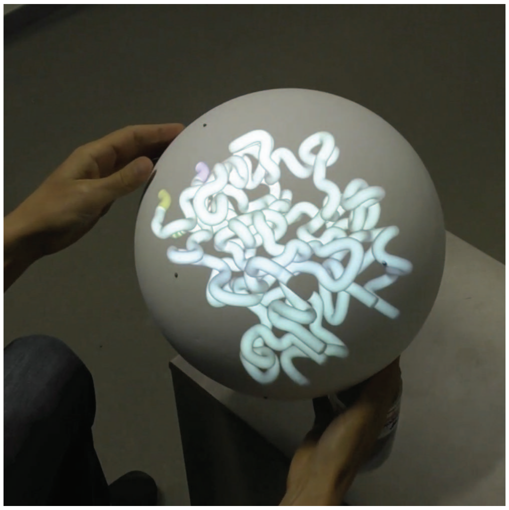

Figure 1: A display-fixed scene: a spaghetti puzzle.

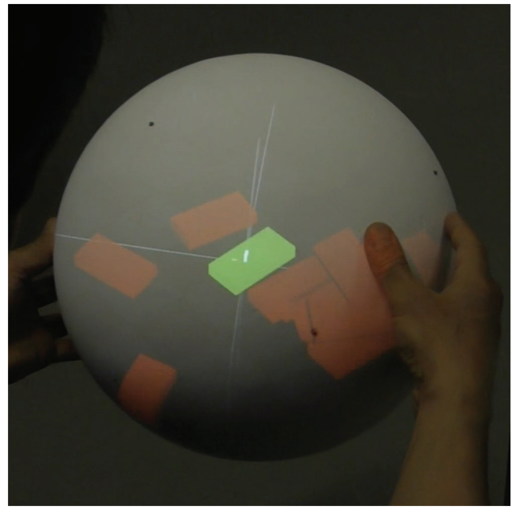

Figure 2: A world-fixed scene: a cube game.

Index Terms: Computing methodologies—Computer graphics—Graphics systems and interfaces—Mixed / augmented reality Human-centered computing—Human computer interaction (HCI)—Interaction devices—Displays and imagers;

1 Introduction

Perspective Corrected Displays (PCDs) show the perspective projection of a 3D scene computed from the viewer's position that is updated in real-time. By moving their head in front of the display, users perceive the motion parallax effect, a strong depth perception cue [6]. "fish-tank virtual reality" systems are well-known instantiation of PCDs involving a fixed planar display and stereo rendering is added to the motion parallax depth cue [5]. More recently, PCDs have been arranged to form small volumes such as a cube (i.e. gCubik [2] and pCubee [4]). This gives the illusion that the scene is contained inside the display. Because of the small size of the displays, users can rotate them in their hands, hence the *Handheld* in HPCD. This creates the strong illusion of holding the virtual scene in one's hands. In addition, rotating the display in hands requires much less effort than moving the whole body in front of the display. Hence, HPCDs allow users to experience more motion parallax than PCDs. However, the two previous implementations of cubic HPCDs required the presence of complex electronic on the display. As a result, they are connected with a thick wire to a rendering computer. This prevents to display on all faces as one of them is used for the connection. In addition, a significant part of the cube's sides is occluded by the displays' bezels.

*e-mail: francois.berard@univ-grenoble-alpes.fr
†e-mail: thibault.louis@univ-grenoble-alpes.fr

We propose to demonstrate a novel approach to HPCD implementation using video projection: a single projector creates the image on a passive display, as illustrated on Figure 3. The passive display can be a physical object of any convex shape: we experimented with cubes and spheres of various sizes. The display is made of lightweight material, such as polystyrene; and is only equipped with passive markers for tracking. As a result, the device allows agile manipulation and minimizes the fatigue of holding it in the air. We use a high definition projector to offer a high-resolution rendering of the scene (a limit of gCubik) and a 120 Hz update rate to offer stereo rendering (a limit of pCubee).

2 Explanation of the Demonstration

Our system works for a single user as it shows images that are perspective corrected for a single pair of eyes. The user sits underneath the projector as illustrated on Figure 3 and wears active shutter stereo glasses. The glasses are equipped with passive retro-reflexive markers; which are tracked by an Optitrack optical tracking system. The user takes a sphere in both hands. The sphere is large (30 cm of diameter) but lightweight (around 0.2 kg). When the interaction with the virtual scene requires clutching, we attach a marker to the user's index finger. We show various virtual scenes through the sphere; which can be either display-fixed of world-fixed.

2.1 Display-fixed scenes

In some cases, the virtual scene is rigidly attached to the sphere, as if it had been glued inside a translucent sphere. This is illustrated on Figure 1 with the spaghetti puzzle object used in a user study. We will also demonstrate a 3D labyrinth marble game using a physics engine. The demos illustrate how HPCDs provide a very intuitive, precise and accurate way to control the 6 degrees of freedom (dof) (translations + rotations) of the virtual scene. Indeed, our setup was used to demonstrate its superiority over more common approaches such as using a VR HMD [3]. It should be noted, however, that these

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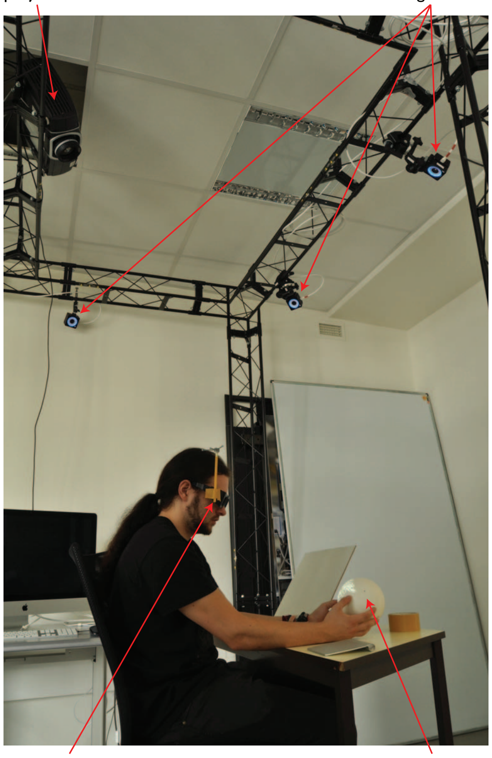

Figure 3: The system setup. The picture shows a 14 cm sphere, we will use a 30 cm sphere for the demonstration, as in Figure 1 and 2

qualities are not beneficial for all 3D perception tasks. For example, the exploration of complex object does not require precision nor accuracy [1].

2.2 World-fixed scenes

In some cases, the virtual scene can be attached to the world, and the sphere act as a window into the virtual world. We will demonstrate a bricks game (as illustrated in Figure 2). Here, we demonstrate basic interaction capabilities of HPCDs: a 3D cross is rigidly attached at the center of the sphere, it acts as the cursor. By moving the sphere, users can move the cursor inside of a red virtual brick, the brick turns white. A marker is attached to the user's index finger for clutching: when the marker is inside a brick and the user clutches by touching the sphere with the index, the selected brick turns green and is now rigidly attached to the sphere, until the index is raised from the surface of the sphere[1]. Here again, this reveals the intuitiveness, precision and accuracy of 6 dof control of the bricks; which can easily be assembled into towers, for example, despite the lack of tactile feedback. We will also demonstrate a map application showing how the system can be used to easily navigate a 1/25000 tourist map of the entire French alps (a 19Gb database).

3 What makes it unique and special

Our system has several unique features. It is the first high-resolution (around 100 dpi) stereo Handheld Perspective Coupled Display. It is untethered and very lightweight; which yield very agile manipulations. If offers a seamless display as there is no bezels on the sphere.

We took great care to accurately calibrate the system. We use a sub-millimeter tracking system, and we custom-developed a semi-automated projector calibration procedure that yields sub-millimeter accuracy in all parts of the projection frustum.

We took great care the minimize the latency of the system by creating a specially crafted event and display refresh loop. We accurately measured its baseline latency to 27 ms (21 ms of which coming from the input lag of the projector). We use a simple prediction to compensate this latency in order to achieve a virtually latency free system[2]

The high-quality rendering in stereo, the agility of the display, the precision and low latency of the tracking, all contribute to create one of the most convincing illusion of presence of a virtual scene. We received many comments from participants of our user experiments that "this was the real thing", that it was as if there was a real object inside the sphere.

4 Why will it draw a crowd?

Because of the feeling of holding a very convincing virtual object in one's hands. Because of the ease of learning how to control bricks, and the ease of building a tower and destroying it by throwing a virtual brick at it.

Please note that videos don't do justice to the system, as stereo can't be enabled. This is our main motivation to make the first public demonstration of the system, as nothing can replace actually experimenting with it to feel how it works.

5 Keywords

handheld device, perspective corrected display, stereo display, 3D interaction

Acknowledgments

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[1] A video of the bricks game is available in the second part of: http://brouet.imag.fr/fberard/Research/CHI17a?action=download&upname=lastest_dev.mp4

[2] For an illustration of the latency of the system, see http://brouet.imag.fr/fberard/Research/CHI17a?action=download&upname=lastest_dev.mp4