gCubik+i Virtual 3D Aquarium: Interfacing a graspable 3D display with a tabletop display

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Abstract

We propose gCubik+i as a new interactive platform that naturally interfaces a 3D display with a tabletop display. The proposed platform is suitable for group collaboration and it introduces two novel interaction paradigms to existing tabletop display applications: 1) natural switching between the shared working spaces of the table and the users' hands; and 2) transforming static 2D images into interactive 3D images that can be viewed and manipulated as if holding a real object. This paper describes the conceptual design and prototype implementation of the gCubik+i platform along with a description of its 3D virtual aquarium application.

Categories and Subject Descriptors (according to ACM CCS): Computer Graphics [I.3.1]: Hardware Architecture—three-dimensional displays; Computer Graphics [I.3.6]: Methodology and Techniques—Interaction techniques; Computer Graphics [I.3.8]: Applications—

1. Introduction

In face-to-face collaborative tasks, users often rely on manipulating physical objects on top of a table in order to support their discussion of ideas. Tangible user interfaces leverage our natural object manipulation skills by using physical artifacts as representations and controls for digital information. Physical objects become both the display and the interface to bits of data, thus making the interaction direct and intuitive, leading to "direct engagement" [IU97].

We propose gCubik+i as a new interactive platform that naturally interfaces a 3D display with a tabletop display. A virtual 3D aquarium application that showcases its interactivity potential is shown in Figure 1. The platform introduces two novel interaction paradigms to existing tabletop display applications: 1) natural switching between the shared working spaces of the table and the users' hands; and 2) transforming static 2D images into interactive 3D images that can be viewed and manipulated as if holding a real object.

The following sections describe the proposed platform's conceptual design, its implementaion and discussion of user's experiences interacting with one of its applications.

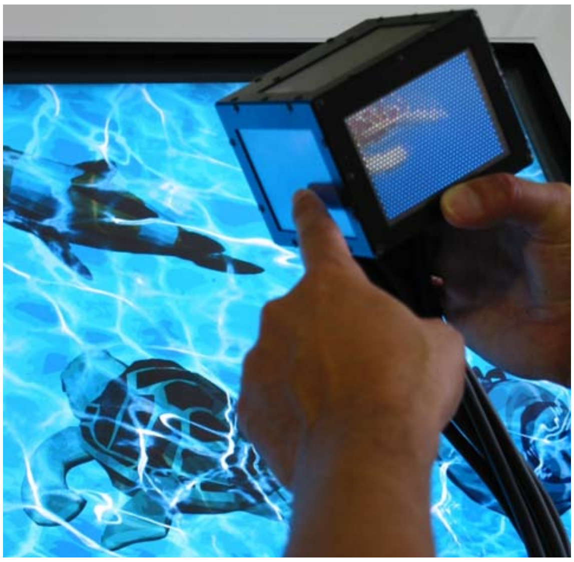

Figure 1: *Interactive virtual 3D aquarium using the gCubik+i platform*

2. Design Concept

The gCubik+i platform aims to to naturally interface a 3D display with a tabletop display. The 3D display would replace real objects with interactive virtual objects, whereas the tabletop display would allow selecting among different virtual objects.

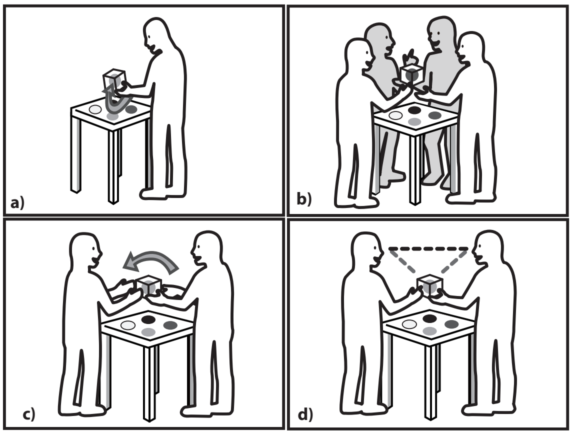

Figure 2: *Desired features of group-shared 3D display: a) graspable display to pick/release virtual object on a table b) simultaneous viewing regardless of users positions; c) natural pointing and easy handing over of the object; and d) natural eye contact*

2.1. Natural interaction

The interaction should be as natural as if users where picking up different objects from a table by simply grabbing them with their hands and bringing them to the center of the group for discussion. Ideally, the 3D display should serve as the displaying device as well as the device to pickup/release virtual objects directly from the tabletop display. In this way, smooth switching between the shared working spaces of the table and the users' hands effectively combines their interaction modes enriching the collaboration. Figure 2 a) shows how the 3D display itself should be used as the device to pick/release virtual objects on the table.

2.2. Group-shared display (4g+i)

In order to naturally replace real objects as part of a group discussion, such a 3D display should provide at least the following characteristics: *g1) Group-shared*: simultaneous viewing for multiple users with correct perspective regardless of their positions, *g2) Graspable*: easy to hold in one hand and pass it over to others, *g3) Glasses-free*: 3D stereo viewing without special glasses, *g4) Glazed-showcase*: give the impression of 3D real objects are inside a transparent case, and *i) Interactive*: provide real-time natural interaction via simple hand or finger gestures.

Figure 2 shows how such a 3D display would provide a shared object of discussion allowing multiple users to simultaneously view the display regardless of their positions. Its compact size would allow easy handing over of the object as well as maintaining natural eye contact among the users during the discussion.

3. gCubik+i Platform

The contribution of the gCubik+i platform is to enhance the gCubik 3D display [LGYYI09], providing real-time interactivity by directly touching its faces, and interfacing it with a tabletop display. The platform also provides a real-time rendering and animation software module for easy application development. The gCubik display supports the *4g* features discussed in Section 2.2.

Figure 3 shows and overview of the gCubik+i platform. The system consists of the gCubik 3D display with touch sensors on all of its faces, a tabletop 32-inch LCD display with an infrared(IR) sensor, a control box for processing input and output of image data and sensors signals, a PC computer for image rendering and signal processing. The tabletop display, together with the IR touch sensor, is used to detect the proximity of the 3D cubic display for interaction.

3.1. Related Work

Various cubic-shaped 3D displays have been proposed before [Ina97] [LSBF09], they are graspable and interactive, providing 3D motion parallax using head-coupled perspective rendering by tracking the user's head. By design, these displays can only support one user at the time, therefore not suitable for our purpose. Even more, providing stereo viewing would require users to wear special glasses or completely redesign the displaying method and its hardware. Using the notation of the previous section, these displays lack *g1* and *g3*.

A number of interactive tabletop displays with multi-user capabilities have also been proposed. For example, the one found in [KKYK01] allows up to four users to simultaneously view and share stereo images with 3D motion parallax by tracking the users' heads. It consists of an stereo display along with a display mask with a hole in its center. However, users need to wear special glasses. Also, users can naturally point at the virtual objects but are not able to grasp them for direct manipulation. This system lacks *g2* and *g3* above.

A number of techniques for interfacing multiple displays that allow multiple users to share virtual objects by transferring them between 2D displays using a simple and intuitive pick-and-drop metaphor can be found in [Rek00]. The system described in [FV02] also combines 2D and 3D displays using a desktop AR system. However, the interaction device and the display are decoupled, as they are also when using [FP00], requiring users to practice with the before mastering the interaction.

Our proposed gCubik+i platform promises to effectively integrate all the "4g+i" requirements discussed above. The following sections describe its implementation details and discuss users' experiences interacting with one of its applications.

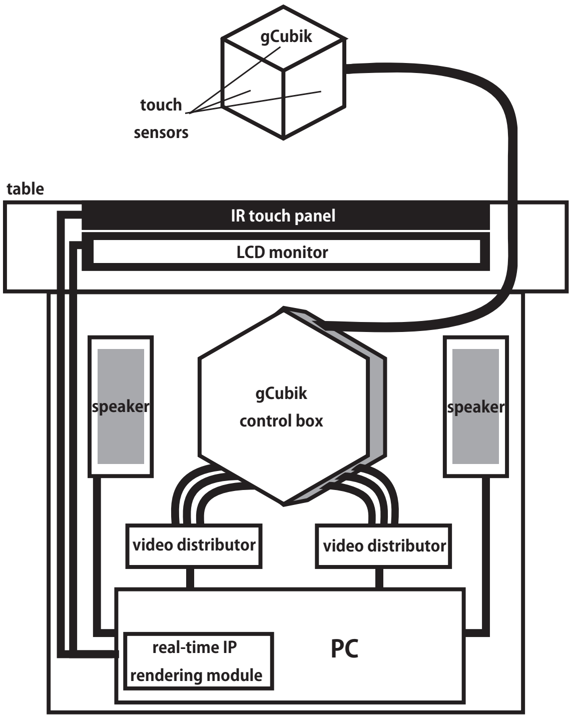

Figure 3: *gCubik+i: System Configuration*

4. Implementation

4.1. Real-time Animation Plugin

We have extended the gCubik's real-time integral photography(IP) rendering algorithm in order to support application development featuring interactive animations. We implemented a plugin architecture, abstracting the rendering algorithm into a module that sits just on top the OpenGL graphics library. Application developers have the flexibility of adding real-time contents depending on their needs and expertise: a generic OpenGL plugin; static 3D model data; or 3D model animation. They are all then passed down to the IP rendering module to generate the images. . Figure 4 shows the IP rendering software architecture of the gCubik.

The generic OpenGL plug-in allows experienced programmers to directly issue OpenGL commands to describe the application's virtual 3D world, its 3D objects and their behaviors. The developer's API consists of four functions: *initGL* and *closeGL*, called only once during the application, mainly used to initialize or destroy the graphics context, load 3D model data, and any other sensor initialization necessary; *tickGL* called once during every loop of the IP rendering process, mainly used to update the virtual objects positions according to sensor data inputs; *drawGL* is called every time an elemental image of the 3D scene is generated, as many as times as the number of IP lenses, 6×1065 in the case of the gCubik display. Therefore any performance optimizations should start by optimizing this function.

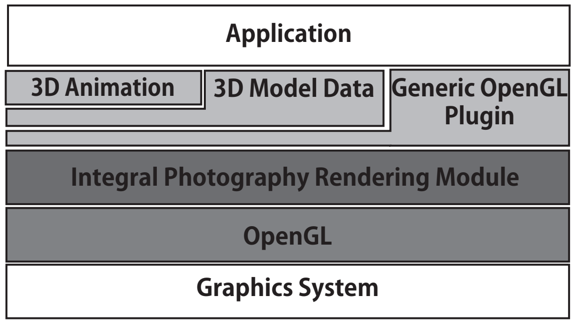

Figure 4: *gCubik IP rendering software architecture, supporting real-time animation*

The 3D model data module can be used to easily load and display 3D objects in different formats. The current implementation only supports the Alias Wavefront OBJ format but other format could be easily added. Graphics designers would use this module to easily display their 3D objects in the gCubik display.

The 3D animation module allows graphics designers and experienced 3D animators to develop animation in the 3D software of their choice. We natively support Quake MD2 animation format files. However, Maya animation files can be also be converted off-line into Quake MD2 animation files for rendering.

4.2. Application

Based on the gCubik+i platform we developed an interactive 3D Virtual Aquarium application. Using the gCubik, users can naturally pick up static 2D fish images from a digital illustrated book on a table and see them transforming into 3D fishes. The 3D fishes in the display are interactive and animated in real-time. They are viewable from any direction without special glasses.

By dragging their fingers on the sides of the display, users can explore different viewing angles of the fishes. Users can also scare away the fishes by repetitively stroking on the faces of the cube, as shown in Figure 1. To release the fish back into the 2D digital book on the table simply touch its previous location. Figure 5 illustrates the flow of steps during the interaction. In the current implementation, there are six fishes displayed on the table.

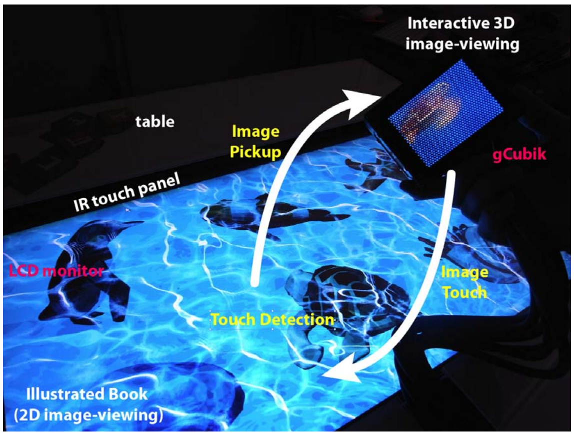

Figure 5: *Interaction process and image exchange flow between the gCubik and a digital illustrated book*

5. Discussion

The gCubik+i and its virtual aquarium application have been exhibited in several major venues. The following discussion is based on video-taped session of users interacting with the system during one of the 4-day exhibits [LGYYI09].

5.1. Natural Interface

Most users found the interface to be natural, direct and intuitive. Occasionally users thought they are actually *fishing* by simply picking up the fishes from the table using the cubic 3D display, as if the fishes were actually *jumping over* when the 3D display approach them. Even users experienced in human-computer-interaction took some time to realize that the only sensor was the IR touch sensor on the table and not a special sensor in the cubic display. We believe this was due to the following factors of the interaction: 1) the cube was the only moving pickup device, 2) the natural hand actions to pickup and release the fishes from the table to the cube, and 3) by effectively removing the fish from the table and transferring into the cube display, instead of simply copying it, distracts the attention of the users into the cube.

5.2. Group Sharing

We also confirmed the natural group sharing features as discussed in section 2.2. Users' gathering around the table and simultaneous pointing were possible given that our display can be viewed, in stereo, from any direction with correct perspective for any given viewpoint. Users would feel as if they were holding and looking at a real object. Handing the display to other users for closer inspection and natural eye contact were possible because our display is compact and graspable. Instead of having users to stare at a shared flat screen as in traditional tabletop displays, users of the gCubik would bring the display closer for inspection and naturally hand it over to others if necessary.

The gCubik+i platform seems to be suitable for collaborative tasks where turn-taking among users would hinder the flow of interaction. The platform effectively integrates the four group collaboration requirements described above.

6. Conclusions

In this paper, we have proposed gCubik+i as a new interactive platform that naturally interfaces a 3D display with a tabletop display. We outlined the conceptual design as well as implementing an interactive virtual 3D aquarium application based on this new platform. Preliminary observations of users interacting with the system suggest that the interaction is natural and intuitive as expected. We plan to develop multi-user applications to explore and evaluate any new interaction paradigms that may evolve from using the gCubik+i platform.

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