3D Tabletop Display Interaction

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ABSTRACT

On traditional tables, people frequently use the third dimension to pile, sort and store objects. People also use the third dimension to communicate through artifacts across the table by orienting them toward other people. The goal of this research is to leverage the freedoms afforded on traditional tables by the use of 3D in the digital realm. We have completed a user study to compare 3D interaction techniques that use only surface interactions on the table and propose two more objectives: (1) to conduct a user study comparing alternative perspective views on a table to better support multiple viewers; and (2) to integrate appropriate interaction with appropriate visual feedback to better support embodiment with digital artifacts on the table.

Categories and Subject Descriptors: H.5.2 [**User Interfaces**]: Graphical User Interfaces (GUI), Interaction styles, Input devices and strategies.

Additional Keywords and Phrases: Tabletop display, object manipulation, multi-user.

INTRODUCTION

On traditional tables, people frequently make use of the third dimension. They make piles for storage, flip paper to make use of its backside, vertically stack books to save space, and reorient objects in a multitude of ways to achieve comprehension, coordination and communication [7]. However, research in tabletop display environments has largely been limited to two dimensions, perhaps due to the 2D nature of the surface itself. Research in 3D virtual environments has typically been explored on vertical displays and usually involves 6DOF (or more) input. Interfaces such as BumpTop [1] begin to move away from these virtual reality environments, but little consideration has been paid to collaboration – neither what effect 3D has on collaboration nor what benefit 3D could provide to collaborative activities. This research will focus on leveraging the interactions already ubiquitous with traditional tables and applying these in the digital realm, thus combining the power offered by technology with these freedoms and reaping the benefits these freedoms provide to collaboration.

Specifically, we will focus on enabling people to simultaneously interact with 3D artifacts on a digital table. We intend to incorporate the ideas in embodied interaction [3] – "the creation, manipulation, and sharing of meaning through engaged interaction with artifacts" (p. 126), using them in such a way that the digital representations themselves can be used as tools within the 3D virtual environment as opposed to merely as objects of enquiry. Furthermore, we intend to develop this type of interaction to specifically support coordination and communication in a collaborative tabletop environment. This embodiment would not only allow digital artifacts to be used as tools, but enable others in the environment to recognize this usage and therefore afford a mutual understanding between collaborators.

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The contribution this work will provide can essentially be summarized as follows:

- We will provide evidence that 3D manipulation and visualization can be supported in a tabletop display environment.
- We will demonstrate that providing 3D capabilities will improve this environment by allowing people to feel as though they are embodied with those objects. Thus, people will not need to concentrate on how to manipulate these objects, but rather can begin to use them as an extension of themselves in order to act with them on other (virtual) objects.
- By providing the ability to use objects in this way, people can more easily coordinate and communicate with one another through the virtual objects at the table.

BACKGROUND

Computing technology has had a large impact on how people work together. Because a large amount of work is now done on a personal computer (intended specifically for individual use) it can be more difficult to collaborate and share work. Tabletop displays offer a promising medium for multiple people to simultaneously interact with a computer, while maintaining some of the abilities to communicate and coordinate that have been lost in this transfer. Tabletop display input technology has been rapidly improving [2, 4] and it may soon be possible for many people to seamlessly and simultaneously control digital artifacts on tables.

In this research, we explore the use of various 3D projections onto the 2D table surface and evaluate whether multiple people can establish a common understanding of a 3D virtual environment. Our work differs from the use of 3D simply as a metaphor (such as in the Pond [9] system) in that full 3D rotations of the artifacts will be provided. We focus specifically on whether this interaction in combination with various visual feedback alternatives can allow embodied interaction and what effect this will have on collaboration.

OBJECTIVES

This work will specifically address three problems: (1) how to interact with virtual objects as though they are real objects, (2) how to present 3D visuals to multiple people at a tabletop display, and (3) how to integrate this interaction with these visuals to achieve embodied interaction.

Problem 1: Can the freedoms of 3D interaction be leveraged using only surface interactions on the table?

When people collaborate around traditional tables, they have the freedom to pick objects up, rotate and manipulate them in ways limited only by the laws of physics. People use these freedoms in many ways: they stack objects for storage or to save space, flip objects to observe other features or to make use of the flipside (e.g., of paper), and often use the orientation of objects to coordinate and communicate with others [7].

When moving to a digital world, artifacts that are displayed on the 2D surface do not inherently have the same freedom of movement. Typically, input devices only allow interaction at the surface of the table and usually with a limited number of contact points (e.g., [2]). The design of how to map these limited surface interactions to artifact manipulation in the virtual environment has a long way to go before reaching the complexity of interaction available with physical objects. It is an open question whether or not the freedoms normally available to people can be leveraged in the virtual world.

Objective 1: Design and evaluate a usable interaction technique for manipulating 3D objects on the table. This objective is near completion and the results have been published [6]. We have conducted and analysed a user study, for which we designed and compared three alternatives for manipulating 3D digital artifacts on a tabletop display: a one-finger technique, a two-finger technique, and a three-finger technique. The techniques use touch interaction on the surface of a DiamondTouch input device [2] with a top-projected display. Participants performed three tasks designed to explore the use of these techniques: a simulated collaborative task, a precise docking task, and a semi-realistic puzzle task. We analysed task completion times, incomplete trials, and preference. We also collected data about how participants used the techniques, including where the participants tended to touch the artifacts.

The results of our study indicated the superiority of the two- and three-touch techniques. The results support the idea that the freedoms of 3D can be leveraged by allowing people to use multiple fingers to manipulate the objects. With the multi-finger techniques, participants reported that the interaction felt more like they were able to "pick up" the objects. Our analysis also suggested that performance was improved when using multiple fingers, due to the ability to control rotation and translation both separately (i.e. each finger was dedicated to either rotation or translation) and simultaneously (since the fingers could be moved together). This ability mirrors that available when manipulating real objects, since we often use different muscle groups to perform translations (e.g., our arms) than to perform rotations (e.g., our wrists).

Thus, in order to support sufficient 3D interactions, more than one touch per person must be provided. By using technology that supports multiple fingers per person at a tabletop display [4], these interaction techniques can truly be supported in a collaborative setting and can begin to allow 3D virtual object manipulation.

Problem 2: Can multiple people share the same 3D display, despite having different viewing angles?

Tabletop displays afford walking around and viewing from multiple different locations. When many people are collaborating around the same shared display, different people will each have a unique viewpoint. Because 3D projections onto a 2D surface typically require an assumption about the location of the viewer's eye, there may be a consistency problem when the same display is used for multiple viewers.

3D perspective projections are particularly robust to off-axis viewing. Thus, it is likely that multiple viewers would be able to each make sense of such a projection, despite their unique viewpoint. However, the image that each viewer sees may be inconsistent with that of their collaborators. Pointing may become more difficult and expectations about (for example) which side of an artifact other people can see may be confusing. This confusion may lead to difficulties in coordinating actions and communicating intention. It is still an open question whether a 3D tabletop interface can be made to overcome this inconsistency.

Objective 2: Design and evaluate various 3D projections suitable for multiple people at a tabletop display. In order to address this problem, we will design various projection solutions and run an empirical study to determine the efficacy of each. The projections we have thus far considered include: standard perspective and orthographic views, both discrete and continuous partitionings of the display so that near objects appear correctly, and a view that allows the user to define (multiple) lenses that each define a camera position and degree of influence. We also wish to explore the presence or absence of other 3D depth cues, such as shading and shadows.

For example, one alternative we have considered is a *continuous partition* of the display (Figure 1). With this method, objects will be rendered to appear "correct" for a person standing at the closest edge of the table and facing its centre. This method addresses the issue of multiple viewers each having a different viewpoint by assuming that each person's "space" or "territory" [8] is closest to themselves. When looking at virtual objects in someone else's space, the object would appear even *more* distorted. This additional distortion may increase confusion. However, it may allow collaborators to more easily recognize a discrepancy, and therefore may prevent confusion in coordinating actions. Our user study will help to determine which effect would win out in practice.

Another alternative would be to provide a mechanism for people to control what objects appear correct and from where (Figure 2). This *customizable perspective* makes it possible to have distant objects appear correct, but also provides a

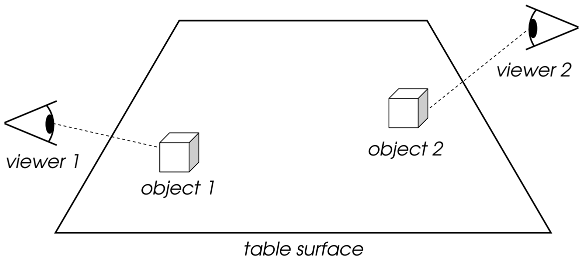

Figure 1: A continuous perspective projection. Objects appear "corrected" toward the closest edge of the table. Object 1 appears correct to Viewer 1, but distorted to Viewer 2. Object 2 appears distorted to Viewer 1 and correct to Viewer 2.

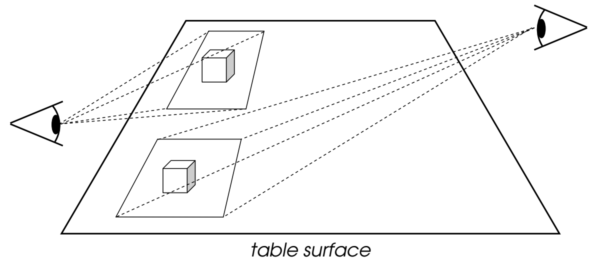

Figure 2: Custom perspective views provide users with control over who can "correctly" view an object. An area can be made to appear correct for any viewpoint. Thus people can coordinate by showing others what their view might be.

means for collaborators to "demonstrate" to others what an object would look like if corrected toward them.

We will observe many people collaborating at a digital display using each of the techniques we have developed in order to determine if they support the coordination and communication we desire.

Problem 3: Can an environment be built that allows embodied interaction with *virtual* 3D objects on a table?
Urp [10] is an example of how tangible media can be used to enrich interaction at a tabletop display. Dourish [3] argues that this system is particularly successful because it enables embodied interaction. With physical objects and tangible media, people are able to establish physical contact and make use of artifacts as tools, instead of as objects of enquiry.

On tables with a projected digital display, it is possible to create virtual renditions of artifacts that are perceptually similar to physical objects. If it is possible to control 3D artifacts with surface interactions (discussed in Problem 1), it may be possible to make such virtual artifacts interactive. It is an open question as to whether this combination of realistic visuals with realistic interaction would allow embodied interaction with virtual objects on a digital table.

Objective 3: Integrate the 3D manipulation and the appropriate projection for a specific task case. After completion of the above two objectives, we will attempt to integrate appropriate 3D interaction with appropriate 3D visuals on a digital table to demonstrate the viability of 3D in this domain. In particular, we intend to demonstrate that we can approach the freedoms available in tangible media systems, such as Urp [10], in a 3D virtual tabletop environment.

In particular, we intend to build an environment that provides virtual tools with which the user can manipulate other objects on the display. For example, a 3D model could be manipulated by providing a "probe" tool or small parts (e.g., vertices) could be manipulated with a "tweezer" tool. With the interaction techniques designed in Objective 1, people would be able to essentially "pick up" these tools as though they were real objects and use them to perform the desired action. Although the interaction with these tools would resemble interaction with a real object, physically impossible interactions (e.g., scaling, warping, automatically aligning) could still be accomplished using the same physical motions.

By creating such a system, we intend to demonstrate that people can become embodied with 3D virtual objects. Thus, by acting through these objects, multiple users can more easily coordinate activity and communicate with one another. For example, the act of "picking up" a probe would indicate to all at the table the intention to explore the 3D model. The direct connection between the person and the tool (i.e. the embodiment) would maintain the awareness of that user's actions as they perform that probing. This form of interaction can provide this communication without interfering with the act of probing itself — the tool can become an extension of the person and be ignored as they probe the 3D object.

CURRENT STATUS & CONCLUSION

This work was successfully proposed in the Fall of 2006. The second objective has also been completed and published [6]. We have designed a variety of multi-person alternatives for projecting 3D on a table and have published this work at Tabletop 2007 [5]. We intend to fully design and implement the user study for the second objective by the end of this year. Work will then begin on the final step of integrating the two first objectives into a viable tabletop interface that allows embodied interaction with virtual objects.

This research is the first steps toward leveraging the freedoms available through 3D interaction on traditional tables with virtual objects on digital tables. This process will involve three primary objectives: (1) to provide suitable techniques for manipulating 3D objects through surface interactions on the table, (2) to provide appropriate 3D visual feedback for multiple users at a tabletop display, and (3) to integrate these visuals and interaction techniques into a system that demonstrates the need and viability of 3D interaction on digital tables.

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