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Mockup Builder: 3D modeling on and above the surface

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ABSTRACT

We present Mockup Builder, a semi-immersive environment for conceptual design which allows virtual mockups to be created using gestures. Our goal is to provide familiar ways for people to conceive, create and manipulate three-dimensional shapes. To this end, we developed on-and-above-the-surface interaction techniques based on asymmetric bimanual interaction for creating and editing 3D models in a stereoscopic environment. Our approach combines both hand and finger tracking in the space on and above a multi-touch surface. This combination brings forth an alternative design environment where users can seamlessly switch between interacting on the surface or above it to leverage the benefit of both interaction spaces. A formal user evaluation conducted with experienced users shows very promising avenues for further work towards providing an alternative to current user interfaces for modeling.

1. Introduction

Despite the growing popularity of virtual environments, they have not yet replaced desktop Computer Aided Design (CAD) systems when it comes to modeling 3D scenes. Traditional virtual reality idioms are still umbilically connected to the desktop metaphor they aim to replace, by leveraging on the familiar "Windows, Icons, Menus, Pointing" (WIMP) metaphors. Worse, the command languages underlying many of these systems do not map well to the way people learn to conceive, reason about and manipulate three-dimensional shapes.

In this paper, we explore 3D interaction metaphors to yield direct modeling techniques in stereoscopic multi-touch virtual environments. Combined with user posture tracking based on a depth camera and three-dimensional finger tracking, this rich environment allows us to seamlessly pick and choose the sensing techniques most appropriate to each modeling task. Based on this groundwork, we have developed an expressive set of modeling operations which build on user's abilities at creating and manipulating spatial objects. Indeed, from a small set of simple, yet powerful functions, users are able to create moderately complex scenes with simple dialogues via direct manipulation of shapes in less cumbersome ways. Our immersive environment aims at supporting gestural and direct manipulation following a push-and-pull modeling paradigm to edit both topological and geometric representations of 3D models. By doing so, our goal is to propose plausible 3D gestures for modeling fashioned after physical mock-up interaction. Finally, we want to hide the underlying mathematical details associated to traditional CAD systems, thus affording users more intimate contact with virtual shapes without sacrificing their creativity. While we do not envisage working at full size, the ability to control scale at will is an important feature to easily explore models. By using a godlike view, we render virtual models as close as possible to physical mockup-ups without the associated physical constraints. While the bimanual interaction model has been previously published using a similar hardware setup in [1], this paper describes an extended version of the work presented at the ACM CHI workshop on the 3rd dimension of CHI (3DCHI) [2] focused on the 3D modeling techniques and their evaluation. We performed a formal user evaluation to assess the benefits and limitations of our approach as compared to a CAD modeling system with similar push and pull modeling ability.

The remainder of the paper is organized as follows. After an overview of the related work we introduce our modeling setup and our modeling approach. We then present the results of a preliminary evaluation comparing Mockup Builder to Rhino 3D with two experts and continue with a formal user evaluation with 14 participants to compare Mockup Builder to Sketchup 8 in different modeling scenarios. We finish by devising areas for improving Mockup Builder based on these evaluations before concluding.

2. Related work

Several strategies have been followed to propose expressive and easy-to-learn user interfaces that support 3D modeling tasks.

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To take advantage of both stereoscopic displays and gestures in free space, Schkolne et al. [3] introduced surface drawing using hand motions in the air to describe ribbon-like shapes based on hand posture. Additionally, a set of tangible tracked artifacts were available, each with its own modeling functionality. While this approach allows creating free-form shapes, it appears inadequate to create rigorous manufactured shapes. FreeDrawer [4] alleviates this issue by providing a tracked stylus allowing the user to sketch networks of curves on top of a Responsive Workbench. These curves can then be used to define the boundary of free-form surfaces that can be interactively deformed. However this approach does not support more complex CAD editing and primitives. The system proposed by Fleish et al. [5] supports both freeform shape creation and regular CAD primitives by adapting traditional WIMP based interfaces to virtual immersive environments using a transparent PIPSheet artifact to map menus. Their system can be used by several users in a collaborative way to support the designing task as presented by Kaufmann [6] using head mounted displays. However the lack of physical support makes drawing in empty space more adequate to free form modeling than creating 'constructive solid geometry"—like regular objects [7]. Haptic devices can help sketching in the air although their working space is often restricted [8]. This provides an attractive solution for 3D modeling since users are able to easily learn how to use these systems and rigor improves rapidly with training as shown by recent studies [9]. Instead of only relying on gestures in empty space, our approach takes advantage of both the surface and space above it for what they are best designed for, to combine the benefits of both interaction spaces.

Sketching is a powerful communication tool of any real conceptual design task. However it is still discarded by most existing CAD modeling systems which rely primarily on single cursor based interaction and WIMP metaphor. Regarding traditional 2D environments, research on sketch based modeling interfaces has proposed several approaches to take advantage of designer drawing skills. Olsen presented a deep survey of most existing techniques [10]. These systems rely on gesture recognition (SKETCH), stroke beautification (Pegasus), line drawing reconstruction (SmartPaper), suggestive interfaces (Chateau), push-and-pull sketching (Sesame), freeform contour based inflation (Teddy or ShapeShop) to make sketching as a usable alternative to traditional CAD systems. We invite the reader to refer to this survey for further details regarding these systems and techniques. Forsberg et al. [11] propose an adaptation of the SKETCH system to a stereoscopic ActiveDesk environment named ErgoDesk. However they still rely exclusively on 2D gestures to create geometry using a light pen and the stereoscopic visualization is primary used for 3D exploration of shapes using a 6DoF tracker. Our approach adopts several of these techniques to go further than existing drawing-in-the-air approaches while mixing 2D sketch with 3D gestures continuously.

With the widespread adoption of multi-touch devices and less expensive and intrusive tracking solutions such as the Microsoft Kinect, academic research on tabletop has refocused on "on" and "above" surface interaction techniques. Müller-Tomfelde et al. proposed different methods to use the space above the surface to provide ways of interacting with 2D tabletop content closer to reality [12]. While tangible devices complement the surface physically with a direct mapping to the GUI such as in the Photohelix system and StereoBlocks [13], gestures above the surface mimic physical interaction with real objects. Tangible interfaces offer natural manipulations and artifacts can correctly map tools functionality [3]. They can be as effective or even better than WIMP interfaces for 3D manipulation and edition as demonstrated by Novotny et al. [14]. Wilson et al. proposed several metaphors to interact with different displays while capturing full body posture [15]. Users can also interact physically in space with projected GUI. In contrast to tangible interfaces, our approach is not limited to physical representations and provides an unconstrained design environment for shape representation. Regarding user interface, we prefer to use the surface for GUI since it is more adequate for discrete selection and explore space gestures for modeling actions.

Our approach explores the continuous space as presented by Marquardt et al. [16]; however we extend their approach by combining it with the bimanual asymmetric model proposed by Guiard [17]. This model proposes guidelines for designing bimanual operations based on observations of users sketching on paper. Guiard identified different rules and actions for the preferred (also dominant-hand or DH) and non-preferred (also non-dominant hand, or NDH) hand. While the DH performs fine movements and manipulates tools, the NDH sets the spatial frame of reference and issues coarse movements. This approach has been explored by several systems [18–21] by combining finger- or hand-gestures with pen devices. Brandl et al. proposed a sketching system where the user selects options through touch using the NDH on a WIMP-based graphical interface, while the DH sketches using a pen device [18]. Such a configuration allows to better explore hand gestures proposing richer interaction concepts to represent 2D editing operations such as demonstrated by Hinckley et al. [19]. Indeed, this makes switching between modalities easier and allows users to perform a wide range of 2D editing tasks without relying on gestures or GUI invocations. To model 3D curves, Lee combined hand gestures with sketching using a collapsible pen to define curve depth on a tabletop [20]. The NDH is tracked allowing users to seamlessly specify 3D modeling commands or modes such as the normal direction of an extrusion while specifying the displacement by interacting with the pen on the virtual scene. Contrary to their approach, we prefer to keep the surface for fast and accurate 2D drawing, while benefiting from the 3D input space for controlling depth directly. Lopes et al. adapted the ShapeShop sketch based free-form modeler to use both pen and multi-touch simultaneously [21]. They found out that the asymmetric bimanual model allows users to perform more manipulations in less time than conventional single interaction point interfaces, which increased the percentage of time spent on sketching and modeling tasks. By tracking user hands, we adopt the asymmetric bimanual model to easily switch between sketching, model editing, navigation and spatial manipulation of objects. In addition, we do not need to rely on special input devices nor extra modalities to assign different roles to each hand.

We rely on a stereoscopic visualization setup for architectural model visualization similar to [22]. While this system allows navigating or annotating the 3D scene mainly as if it were inside the table and use fingers as proxies over the scene, our interaction techniques focus on modeling and direct manipulation since 3D models are rendered as if they were lying atop the table. To avoid hand occlusions over the visualization, Toucheo [23] proposed a fish-tank like setup using a multi-touch surface and a stereoscopic display. However similar to other setups relying on semi-transparent mirrors to create an holographic illusion, it both reduces the working space and constrains using the above surface space to hand gestures. Thus, our stereoscopic visualization setup provides more freedom of movement allowing a continuous space of interaction. In addition, adopting a bimanual asymmetric model makes it possible to develop new interaction techniques which could benefit interaction with holographic display technologies when they become available.

3. Hardware modeling setup

Our semi-immersive environment uses a stereoscopic multi-touch display 140×96 cm combined with a Kinect depth camera