Beyond – Collapsible Input Device for Direct 3D Manipulation beyond the Screen

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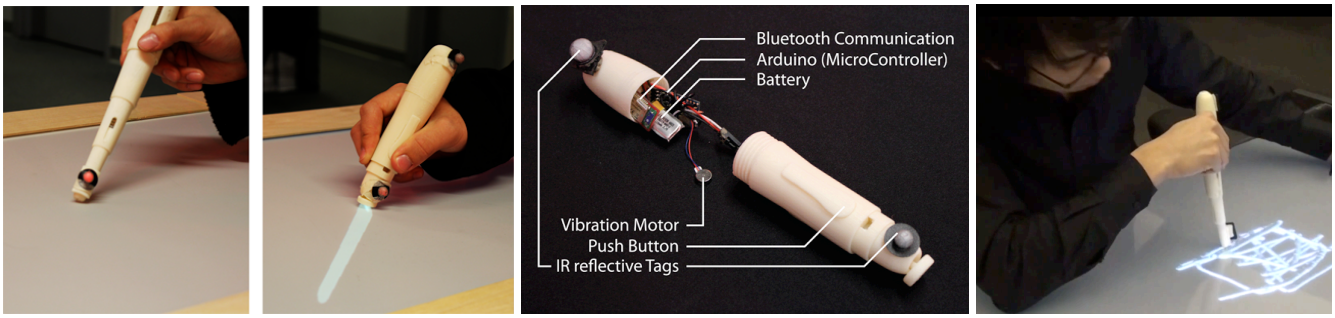

Figure 1. (a),(b): The *Beyond* device collapses in the real world and project itself into the digital space. (c): Inside the *Beyond* Device (d): Direct Sketching and manipulation in 3D with the *Beyond* Device.

ABSTRACT
What would it be like to reach into a screen and manipulate or design virtual objects as in real world. We present *Beyond*, a collapsible input device for direct 3D manipulation. When pressed against a screen, *Beyond* collapses in the physical world and extends into the digital space of the screen, such that users can perceive that they are inserting the tool into the virtual space. *Beyond* allows users to directly interact with 3D media, avoiding separation of the users' input and the displayed 3D graphics without having to wear special glasses, such that users can select, draw, and sculpt in 3D virtual space. We describe detailed interaction techniques, implementation and application scenarios focused on 3D geometric design and prototyping.

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General terms: Design, Human Factors

Keywords: Input and Interaction Technologies, Pen and Tactile Input, Interaction Design, Tabletop UIs, User Interface Design, 3D Interaction, Augmented Reality, Virtual Reality, Pen-Based UIs

INTRODUCTION

Computational tools for 3D modeling are becoming more available. Despite these trends, few have been widely utilized in the early stage of prototyping since most of the computational modeling interfaces are indirect, and also complicated for non-expert drafters to learn. In an attempt to make the computational design process more straightforward and easy-to-learn, various techniques for 3D direct manipulation have been suggested.

A common technique for 3D interaction has been mapping both 2D input to 3D images projected to the 2D display surfaces [1]. Combining touch and tangible controllers can allow for 3D interaction on the interactive tabletop surfaces [2]. Having a 3D point cursor directly mapped to the hand position or projecting a ray from the users' hand have been two common ways of directly mapping user's 3D input to displayed 3D images [3]. Hilliges et al [4] suggested combining this technique with the digital shadow of users' hands to allow for above-the-table interaction. In these scenarios, however, users' bodies still remain separate from the screen, causing ambiguities in interfaces due to separation of the users' input and rendered graphics[5]. While wearing Head Mounted Displays (HMD) and haptic mechanical devices can diminish this separation, it greatly isolates users from the real-world context, which is crucial for the early stage of design process.

In an attempt to resolve these drawbacks of each approach, our paper proposes *Beyond*, a 3D interface where users can directly manipulate and design 3D geometry without being detached from the real world.

BEYOND: COLLASPIBLE DEVICE FOR 3D DIRECT MANIPULATION

Beyond is a novel 3D interface based on a collapsible input device that users can press into the screen to directly manipulate 3D mediain the digital realm. The device can retract and project itself onto the screen, letting users perceive that they are inserting the device into the graphical display. Users can directly select, draw and sculpt, in 3D

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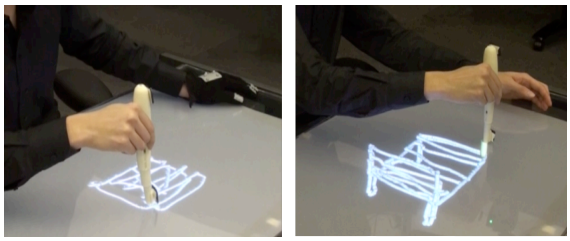

Figure 2: Comparison between the pictures of the rendering based on the perspective fixed at the user's position (left) and at the camera's position (right).

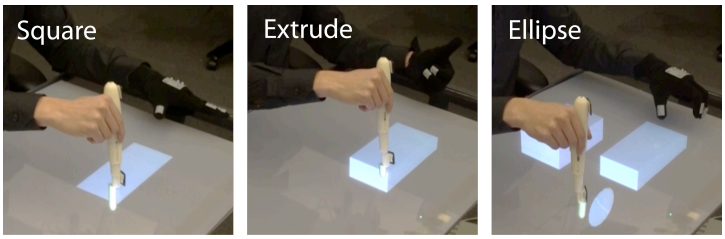

Figure 3: Users can define abstract shapes and operate functions using gestures of non-dominant hand. (3D Scene in the picture was rendered based on the camera's perspective instead of the user's to illustrate how it looks from the user's point of view).

virtual space without having to wear special goggles or HMD, since the scene is being rendered based on the user's head position tracked by a camera.

Collapsible Device

The Beyond device is composed of a telescoping plastic body with a push button housing, a Bluetooth communication module, and a vibrating motor controlled by an Arduino Board (see Figure 1. (c)). Two passive infrared reflective markers are attached to the both ends of the device.

Tracking and Rendering

Tracking of both sides of the device is accomplished using a Vicon system, which illuminates and captures infrared light reflected by the attached retro-reflective tags (see Figure 1.(c)). The position of the user's head is tracked by two additional cameras with a face–tracking algorithm. The perspective of 3D scenes is corrected based on the users' head position such that they can look at the virtual objects from different angles by simply moving their head [6].

DIRECT SKETCHING AND MODELING IN 3D

By supporting straightforward 3D selection and manipulation, *Beyond* serves as an intuitive 3D sketching and modeling tools, minimizing unnecessary abstractions in interfaces. Beyond allows the user to draw, sculpt and define shapes directly in 3D space without having to map the 3D geometry into multiple 2D constructional plans. Such an interaction allows users to rapidly externalize their ideas and share with others (see Figure 2).

Bimanual Input with Gestures

Through short experiments, we found it intuitive to use gestures of non-dominant hands to imply abstract functions or shapes, combined with dominant hands' direct manipulation with the *Beyond* device (see Figure 3). In our 3D sketching application, users can define lines, curves, squares, and ellipse and extrude or rotate surfaces with predefined gestures developed by oblong industries [7].

CONCLUSION AND FUTURE WORK

We have presented *Beyond,* a novel interface that allows direct 3D manipulation for modeling and prototyping based on a collapsible input device that users can grab and press onto the screen. Our work makes distinct contributions on the existing literature of 3D interaction in Virtual Reality and tabletop interfaces: *Beyond* enables direct 3D manipulation, resolving the issue of the cognitive separation of the users' input and rendered graphics, without requiring users to be instrumented with HMD or special goggles. We believe the *Beyond* can serve as an intuitive computational prototyping tool, helping users to think and express in 3D.

While the current *Beyond* platform does not fully support multi-user interactions because of the view-dependent perspective correction, this can be largely resolved by using volumetric or lenticular lens-based light-field displays. We further plan to implement this interface with a tablet and a device that can sense tilt and retraction, which will greatly improve portability of the system.

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