

## MIT Open Access Articles

### *Beyond: collapsible tools and gestures for computational design*

The MIT Faculty has made this article openly available. **Please share** how this access benefits you. Your story matters.

**Citation:** Jinha Lee and Hiroshi Ishii. 2010. Beyond: collapsible tools and gestures for computational design. In CHI '10 Extended Abstracts on Human Factors in Computing Systems (CHI EA '10). ACM, New York, NY, USA, 3931-3936.

**As Published:** <http://dx.doi.org/10.1145/1753846.1754081>

**Publisher:** Association for Computing Machinery (ACM)

**Persistent URL:** <http://hdl.handle.net/1721.1/79882>

**Version:** Author's final manuscript: final author's manuscript post peer review, without publisher's formatting or copy editing

**Terms of use:** Creative Commons Attribution-Noncommercial-Share Alike 3.0



---

# Beyond – Collapsible Tools and Gestures for Computational Design

**Jinha Lee**

MIT Media Laboratory  
E14 20 Ames St.  
Cambridge, MA 02143 USA  
jinhalee@media.mit.edu

**Hiroshi Ishii**

MIT Media Laboratory  
E14 20 Ames St.  
Cambridge, MA 02143 USA  
ishii@media.mit.edu

**Abstract**

Since the invention of the personal computer, digital media has remained separate from the physical world, blocked by a rigid screen. In this paper, we present Beyond, an interface for 3-D design where users can directly manipulate digital media with physically retractable tools and natural hand gestures. When pushed onto the screen, these tools physically collapse and project themselves onto the screen, letting users perceive as if they are inserting tools into the digital space beyond the screen. The aim of Beyond is to make the digital 3-D design process straightforward, scalable and more accessible to general users by extending physical affordances and inherent senses of 3-D space beyond the computer screen.

**Keywords**

3D Interaction, Augmented Reality and Tangible UI, Pen and Tactile Input, Tactile & Haptic UIs, Pen-based UIs, Tangible UIs

**ACM Classification Keywords**

H5.m. Information interfaces and presentation (e.g., HCI): H.5.2. Input Devices and Strategies.

## Introduction

Recent developments in computer technologies have made the design process much more precise, fast and scalable. Despite this powerful role the computation plays in design, many designers and architects prefer to build physical models using physical tools and hands, employing their versatile senses and bodily expressions in their early stage of design [17].

Tangible User Interfaces have appeared as a strong concept to leverage these traditional ways of design with digital power, while preserving physical affordances, by blurring the boundary between the physical environment and cyberspace [1]. In an attempt to diminish the separations between visual and tactile senses, which are critical for the design process, researchers of Augmented Reality (AR) have suggested several input devices and ways of displaying digital information in more realistic ways [8][9][10][11]. Despite these efforts, a flat monitor and a mouse remain our standard interfaces for design, leaving digital media apart from the physical world blocked by a rigid screen. It is extremely hard for users to select a certain 3-dimensional coordinate in virtual space and sense the volume without wearing special display glasses and using complicated mechanical structures.

A parallel trend in CAD, development in gestural interface, has allowed users to employ bodily expressions in data manipulation [14]. However, simple combinations of mouse and bodily gesture can hardly cover a large number of the commands necessary in design, leading users to rely on GUI tool menus.

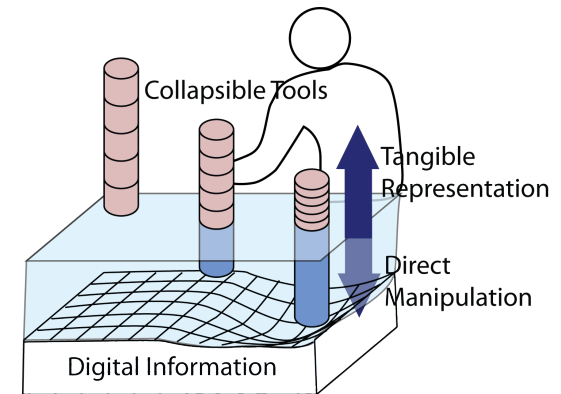


Figure 1. Direct manipulation of digital information beyond the screen with collapsible tools

In this paper, we present *Beyond*, an interface for 3-dimensional design where users can directly manipulate 3-D digital media with physically retractable tools and natural hand gestures. When pushed onto the screen, those tools physically collapse and project themselves onto the screen, letting users perceive as if they are inserting tools into the digital space beyond the screen. Our research aim is to make the digital 3-D design process straightforward, scalable and more accessible to general users by extending physical affordances and inherent senses of 3-D space beyond the screen.

## Related Work

There have been various approaches to enable users to design in 3D with more straightforward and intuitive manners by integrating input and output and by providing users with tangible representations of digital media [1].

The concept of WYSIWYF – “what you see is what you feel” – has been suggested in the domain of

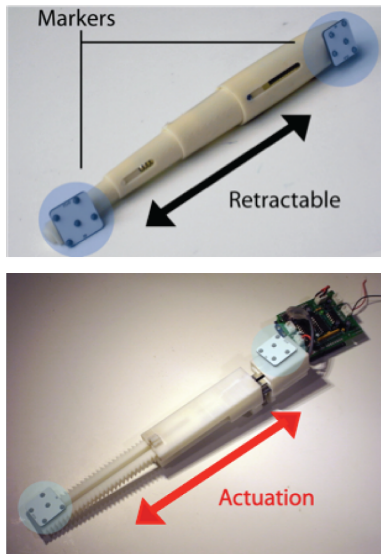


Figure 2. Collapsible pen (Top) and saw (bottom)

Augmented Reality in an attempt to integrate haptic / visual feedback [8]. Technologies like stereoscopic glasses for 3-D display, holograms and wearable mechanical devices such as phantom that provide precise haptic feedbacks are invented and experimented within this context [18][15]. Many of the systems require users to wear devices, which are often heavy and cumbersome, intervening natural views and behaviors of the users. Sand-like beads or actuated pin-displays are examples of deformable physical materials built in an attempt to diminish the separation between input and output.[21]. However, they are often less scalable since solid forms embedded in physical materials are less malleable than pixels;

In an effort to convey users' intentions more intuitively, gesture based interactive sketch tools have been suggested [2][13]. Most of the systems are based on pen-stroke gesture input, whose functions are limited to simple instant ones such as changing the plane, erasing. Oblong's g-speak is a novel gestural interface platform that supports varieties of gestures and applications including 3-D drawings [3]. However it is still a hard task to select a certain coordinate in arbitrary space with these systems.

### What is Beyond

Beyond is a design platform that allows users to employ their gestures and physical tools beyond the screen in 3-D design. Collapsible tools are used in Beyond so that those can retract and project itself onto the screen, letting users perceive as if they are inserting the tools into the screen. Users can design and manipulate digital media, with affordances they have with physical

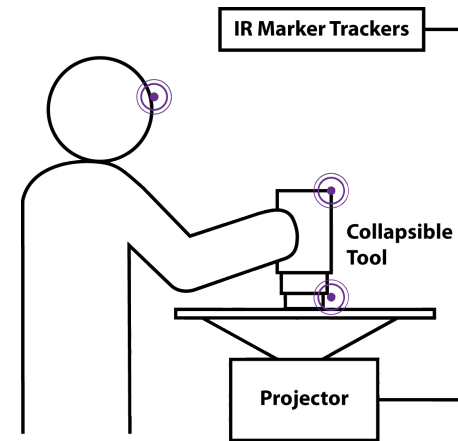


Figure 3. Mechanism for tracking head and tools' positions

tools and operating abstract commands with their gestures.

### Beyond Prototype

The current Beyond prototype consists of retractable tools, a table-top display and an infrared position tracking system.

The Tools are designed to retract and stretch with two IR retro-reflective markers attached on both tips. Vicon system is used to track these markers, letting the system obtain information about location, length and tilt of the tools. An additional marker can be attached to the users' head for real time 3D rendering [16].

We implemented two kinds of collapsible tools for the first prototype of Beyond: Pen and Saw (Figure 2).



Straight Line



Square



Ellipse



Extrude



Surface Lock



Move with Directions

Figure 4. Gestures used in Beyond Prototype

### Pen

The pen serves as a tool for form giving. This passive tool can select any 3D coordinate in virtual space within its reach and draw shapes and lines.

### Saw

The saw serves as a tool for cutting and sculpting. It is designed to provide several different forms of physical actuation when users touched virtual objects.

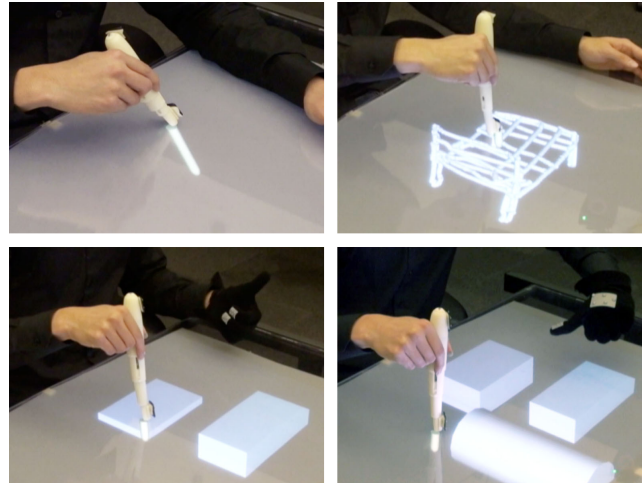


Figure 5. Rough 3D sketch (top) and abstract shape drawing (bottom) using gestures.

### Gestures

Beyond uses several gestural interaction techniques mediated by gloves tagged with IR reflective markers traced by Vicon tracking technologies, developed by oblong industries.

### 3-D rendering techniques based on users' head position

In order to render the scene where physical and digital portions are seamlessly connected, we implemented a software to render 3D scenes based on users' head position.

## Interaction with Beyond

### Direct Selection and Drawing

Beyond allows users to directly select certain 3D specific coordinates within its physical reach of physical tools in virtual 3D space without looking at multiple planes or wearing head mounted display. This enables users to sketch in 3D shapes in a straightforward manner, help them externalizing their 3D images in their minds.

### Touching and Cutting

Using Beyond-Saw, users can cut and trim any surface or shape by simply inserting saw tools into the virtual space and use them. When virtual objects are touched or cut, a slide actuator installed inside the saw tool create force feedbacks, making the tools stop retracting further. By doing so users can manipulate digital media with better sense of volume and physical affordances they have with their tools.

### Gestural Interactions with Beyond

Gestural commands effectively compliment tools-mediated direct manipulation, conveying users' intention to the system in intuitive manners. Users can define several different abstract shapes and operate functions while directly specifying the coordinates with the collapsible tools. Figure 4 shows a few examples of several types of gestures. The current Beyond prototype provides shape-related gestural commands

such as straight line, square, ellipse and function-related gestural commands including extrude, lock the drawing surface and move objects.

### **New Work flow of 3-D CAD**

Several interaction techniques illustrated in the previous sections can be merged and weaved together to create a new work flow of 3D computer-aided design as followings. First, users can sketch rough design in 3D with free-line drawing techniques. Next step is to define discreet shape on top of its rough sketch by specifying locations and other critical parameters with tools and operate functions with gestures. In the middle of the design process users can always modify its design by using other types of tools.

### **User Evaluations**

Since the project is currently at its initial stage, we are planning to conduct comprehensive users evaluations in the future. However, overall feedbacks we have received for several weeks have been that the Beyond platform helps users directly externalize and record the 3D shape in their mind and that gestural commands complement directness of tools-based interfaces.

### **Discussion and Future Work**

In this paper, we introduced Beyond, a design platform that enables users to interact with 3D digital media using physically collapsible tools that seamlessly go into the virtual domain by simple mechanism of collapse, projection and actuation. Initial user evaluations showed that applying natural hand gestures to convey abstract intention of users greatly complements tools-mediated direct manipulation. We presented the design and implementation of the first Beyond prototype that

used Vicon location tracking system and the physically collapsible pen and saw.

The Beyond allows users to directly select certain 3-dimensional coordinate in virtual space and helps them physically feel the volume, shape and materialistic feature without wearing special stereoscopic display or relying on complicated mechanical structures. We believe this challenge will help more diverse range of users to access to the technology. While many of the AR or TUI approaches to leverage computational design do not scale up well or too application specific due to inherent rigidity of physical handles, the Beyond platform shows potentials to be a more scalable and generalizable user interfaces by seamlessly transforming rigid physical parts to flexible pixels.



Figure 6. More portable Beyond prototype image, using camera based tracking and touch screen.

Since the Beyond is at its initial stage of developments, we foresee several improvements to Beyond. First, the entire system can be more portable and low-cost by using simple touch screen and camera based tracking technologies. Secondly, we plan to develop more comprehensive gestural languages applicable to design process combined with direct pointing tools. We also plan to improve the force feedback of the active tools by using series elastic actuator, which can create more precise and varieties of force feedback allowing the system to express tactile feedbacks of various materials and viscosities. Finally, we are planning to conduct extensive user evaluations on the system in the near future.

### References

- [1] Ishii, H. and Ullmer, B. Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms. Proceedings of CHI'97, ACM Press, (1997), 234-241
- [2] Bae, S., Balakrishnan, B. and Karan Singh, "ILoveSketch: As-natural-as-possible sketching system for creating 3D curve models," ACM Symposium on User Interface Software and Technology 2008.
- [3] Oblong G-speak. <http://www.oblong.com>
- [4] Revit Architecture. <http://Autodesk.com>
- [5] P. Mistry, K. Sekiya, A. Bradshaw. Inkuitive: An Intuitive Physical Design Workspace. In the Proceedings of 4th International Conference on Intelligent Environments (IE08). 2008.
- [6] Ishii, H., Underkoffler, J., Chak, D., Piper, B., Ben-Joseph, E., Yeung, L., Kanji, Z. Augmented urban planning workbench: overlaying drawings, physical models and digital simulation. In Proceedings of ISMAR. 2002.
- [7] Yokokohji, Y.; Hollis, R.L.; Kanade, T., Vision-based visual/haptic registration for WYSIWYF display Intelligent Robots and Systems apos;1996
- [8] Kamuro, S., Minamizawa, K., Kawakami, N., Tachi, S., Pen De Touch, International Conference on Computer Graphics and Interactive Techniques archive SIGGRAPH '09: Posters, 2009.
- [9] Inami, M.; Kawakami, N.; Sekiguchi, D.; Yanagida, Y.; Maeda, T.; Tachi, S. Visuo-haptic display using head-mounted projector. Virtual Reality, 2000. Proceedings. IEEE, Vol, Issue, 2000. 233-240.
- [10] Plesniak, W.J.; Pappu, R.S.; Benton, S.A. Haptic holography: a primitive computational plastic. Proceedings of the IEEE Volume 91, Issue 9, Sept. 2003. 1443 - 1456.
- [11] Sketch Furniture  
<http://www.youtube.com/watch?v=8zP1em1dg5k>
- [12] Igarashi, T., Matsuoka, S., and Tanaka, H. Teddy: a sketching interface for 3D freeform design. In *Proc. of the 26th Annual Conference on Computer Graphics and Interactive Techniques* ACM Press/Addison-Wesley Publishing Co., New York, NY, 1999. 409-416.
- [13] Igarashi, T. and Hughes, J. F. A suggestive interface for 3D drawing. UIST, 2001. 173-181.
- [14] PhantOM. <http://www.sensable.com/haptic-phantom-desktop.htm>
- [15] Lee, J., Head Tracking Method Using Wii Remote. <http://johnnylee.net/projects/wii/>
- [16] Aliakseyeu, D., Martens, J., Rauterberg, M. A computer support tool for the early stages of architectural design. *Interacting with Computers*, v.18 n.4, July, 2006. 528-555.
- [17] Wang, Y., Biderman, A., Piper, Ben., Ratti, C., Ishii, Tangible User Interfaces (TUIs): A Novel Paradigm for GIS Transactions in GIS, 2004. 407-421.
- [18] Leightinger, D., Kumpft, Adam., Ishii, H., Relief <http://tangible.media.mit.edu/project.php?recid=132>