Augmented Reality & Immersive Sketching

CTHCI 2018 — Philipp Wacker
**Immersive Sketching in AR: Potential Benefits**

- **Immersive Sketching:**
  - No need to compensate loss of one dimension

- **Augmented Reality:**
  - Direct link to the real world \(\Rightarrow\) especially helpful for Personal Fabrication
Augmented Reality
“The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked.”

The Ultimate Display

Sutherland, 1965
Mixed Reality Continuum

- In AV and VE/VR the surrounding environment is virtual, in AR the surrounding environment is real

[Philipp Wacker: Augmented Reality & Immersive Sketching]
A New User Interface Paradigm

- Beginnings in the 1960’s, then into research labs, and since 2005 in commercial applications
- Driven by improvement in display and tracking technologies
- Information is integrated into the user’s perception of the real world
- No standard input devices
- Towards an invisible interface
Definition

• Characteristics for AR system
  • Combines real and virtual objects in a real environment
  • Registers (aligns) real and virtual objects with each other
  • Runs interactively and in real time

A Survey of Augmented Reality
Azuma, 1997
Where to show it?

• Tracking (and registration) technologies
  • To register virtual objects in 3D space and track user input

• Track the
  (a) scene
  (b) the user’s 6DOF viewpoint (head and/or eyes)
  (c) the user’s hands/body for input
  (d) input devices

How to show it?

• Display technologies
  • Show virtual objects overlaying the real world in 3D space
  • Head mounted
  • Spatial
  • Handheld
Displays
Head Mounted Displays

• Optical see-through
  • Direct and better view of the world, safer
• Video see-through
  • Occlusion, wider field of view, better registration and calibration
• Advantages: hands free interaction
• Disadvantages: wearing it (socially and physically)
Spatial Displays

- Spatially aligned displays or projectors
  - Can be wearable
  - Advantages: provide public displays and project on irregular surfaces
  - Disadvantages: brightness, focus, resolution, FOV, and contrast

- Handheld Displays
  - Advantages: widespread, powerful
  - Disadvantages: need to hold the device

[Mistry et al., SIGGRAPH 09]
UNBELIEVABLE
BUS SHELTER

https://www.youtube.com/watch?v=Go9rf9GmYpM
## Comparison

<table>
<thead>
<tr>
<th>Pros.</th>
<th>Cons.</th>
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<tr>
<td><strong>HMD Video see-through</strong></td>
<td>camera and processing, unnatural perception</td>
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<tr>
<td><strong>HMD Optical see-through</strong></td>
<td>more natural perception</td>
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<td><strong>Projectors</strong></td>
<td>displays directly onto physical objects’ surfaces</td>
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<td><strong>Handheld</strong></td>
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Tracking
Tracking and Register Technologies

- Track the user’s viewpoint 6DOF (X, Y, Z, Roll, Pitch, Yaw) and update the appearance of virtual objects
- Register virtual objects in 3D
- Marker tracking vs. World tracking
Marker Tracking

- Visible markers: e.g., fiducial
  - Infrared markers
- Natural features
  - Set of feature points in “normal” images
- Calculate transformation from camera to marker
World Tracking

• Determine the position of the camera
  • Inside-out:
    • Inertial sensors: Compass, accelerometer, gyroscope, etc.
    • Computer vision analysis
  • Outside-in:
    • External tracking e.g., Motion capture systems
Tracking Criteria and Challenges

• Criteria
  • Accuracy, tethering, cost, 6DOF, noisiness, resolution/range

• Challenges
  • Jitter, occlusion, brightness, user and environment changes, latency, ease of calibration

• Choice of tracking technology depends on AR System
Lift-Off: Using Reference Imagery and Freehand Sketching to Create 3D Models in VR

Bret Jackson, Member, IEEE, and Daniel F. Keefe, Senior Member, IEEE

Abstract — Three-dimensional modeling has long been regarded as an ideal application for virtual reality (VR), but current VR-based 3D modeling tools suffer from two problems that limit creativity and applicability: (1) the lack of control for freehand modeling, and (2) the difficulty of starting from scratch. To address these challenges, we present Lift-Off, an immersive 3D interface for creating complex models with a controlled, handcrafted style. Artists start outside of VR with 2D sketches, which are then imported and positioned in VR. Then, using a VR interface built on top of image processing algorithms, 2D curves within the sketches are selected interactively and “lifted” into space to create a 3D scaffolding for the model. Finally, artists sweep surfaces along these curves to create 3D models. Evaluations are presented for both long-term users and for novices who each created a 3D sailboat model from the same starting sketch. Qualitative results are positive, with the visual style of the resulting models of animals and other organic subjects as well as architectural models matching what is possible with traditional fine art media. In addition, quantitative data from logging features built into the software are used to characterize typical tool use and suggest areas for further refinement of the interface.

Index Terms — Immersive 3D Modeling, Virtual Reality, 3D User Interfaces, Sketch-based Modeling

I. INTRODUCTION

Three-dimensional modeling is a fundamental task in computer graphics, and its applications range from product design to art. Yet generating detailed and realistic models remains time-consuming and difficult using conventional user interfaces [31]. While skilled artists are able to create complex models with fine control using current tools such as Maya or 3DS Max, they require extensive training, and many would argue that the complexity of the tools’ interfaces does not effectively support human creativity. For example, we know from creativity support literature that sketching, exemplars, and physical action are all closely associated with increasing human creativity [37], but these techniques are rarely integrated with conventional 3D modeling interfaces. This disconnect is especially evident for free-form artistic or organic modeling (e.g., Fig. 1), as opposed to more engineering-oriented modeling.

In response, the research community has contributed a variety of new user interfaces that focus on 2D sketching as a way to incrementally build a 3D model (e.g., Teddy [14], Modeling-in-Context [26], EverybodyLovesSketch [2]). While these sketch-based interfaces closely align with creative art and design processes, creating 3D models from 2D sketches is a challenging (and typically under-constrained) computational and user interface problem. To avoid modeling errors from depth ambiguity, some 2D sketch-based systems restrict themselves to specific types of models (e.g., teddy bears and other forms based on inflating silhouettes, architectural models and...
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Fig. 1. Lift-Off is an immersive 3D modeling system for artists using a bimanual 3D user interface in virtual reality (VR). After importing hand drawn paper and pencil sketches (a) into VR and placing these in space as virtual slides (white plane in b), 3D models are created using 3D curves (red curves in b) that the artist “lifts off” of the imagery or draws freehand in space. Finally, surfaces are swept along these curves to create virtual sculptures (c).

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Modeling Steps in Lift-Off

1. Position a 2D sketch
2. Select a curve on this sketch
3. Lift the curve into the third dimension ➔ Rails
4. Connect different rails
5. Sweep out a surface
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![3D model of a moose](image-url)
WireDraw: 3D Wire Sculpturing Guided with Mixed Reality

Yue et al., 2017
WireDraw

- Video see-through AR by adding webcams to an Oculus Rift
- Analysis of wireframes to determine optimal sequence of strokes
- The user sees the next stroke and can replicate the model
RoMA: Interactive Fabrication with Augmented Reality and a Robotic 3D Printer

Peng et al., 2018
RoMA: Design Zones

[Peng et al., 2018]
Sketching in immersive 3D virtual reality (VR) environments has great potential for a variety of interactive design applications. Precisely sketching the intended ideas, there has been considerable research into using freehand sketches to create three-dimensional artifacts by lifting 2D sketches into the third dimension. The availability of consumer-grade devices such as HTC Vive and Microsoft HoloLens has enabled development of mainstream and experimental tools for a variety of visual design pipelines such as painting & sketching, 3D modeling, storytelling, and conceptualization.

In this paper, we perform a set of formal experiments to study the human ability to draw in mid-air VR environments, and explore the impact that physical and visual guidance can have on 3D sketching accuracy. We first conduct a series of experiments to analyze the factors which influence drawing in unconstrained, mid-air environments. Our results indicate that the lack of a physical drawing surface is a major cause of inaccuracies in depth perception and drawing accurately in VR is challenging. Inaccuracies in depth perception and drawing in VR are common.

Recent advancements in Virtual and Augmented Reality have enabled development of mainstream and experimental tools for a variety of visual design pipelines such as painting & sketching, 3D modeling, storytelling, and conceptualization. Sketching provides an intuitive method of conceptualizing ideas, designers are excited by the possibility of using direct 3D drawing tools in VR, with and without a force feedback mechanism. However, there have been some quantitative studies exploring how 3D designers are excited by the possibility of using direct 3D sketching tools in VR. While there has been considerable research into using freehand sketches to create three-dimensional artifacts by lifting 2D sketches into the third dimension, there has been limited work that evaluates and quantifies the factors which force feedback affects precision in VR. We found that while additional visual guidance can compensate for the loss of a physical drawing surface, Inaccuracies in depth perception and drawing in VR are common.

In a second experiment we evaluate the extent to which visual guidance can compensate for the loss of a physical drawing surface. In our first study, we directly compare sketching tools in immersive VR, with and without a software projection of a virtual worktable in the background. In our second study, we present a set of controlled studies to analyze the factors which motivate sketching precision in VR. We found that while additional visual guidance can compensate for the loss of a physical drawing surface, Inaccuracies in depth perception and drawing in VR are common.
Mean deviation from target stroke

Traditional

Hybrid

20.2% decrease in accuracy

VR

27.2% decrease in accuracy

[Arora et al., 2017]
For the Interactions deviation trends for circles in Figure 7a. A noticeable effect muscle groups needed to draw on each of the planes.

Figure 8. Depth deviation trends for different conditions (left), and average circle with drawing planes drawing circles curve quality. This is likely due to the difficulty in keeping leads to a hypothesis that participants followed an overly for curves on a plane, the magnitude of the difference was

Figure 12. Effect of pen grip, which was informally observed to change 15cm in front of the participant's head. The orientation is tangential to a hemisphere of radius 40cm, placed approx.

Target Stroke as the rendered surface, as prior research \([2, 5]\) suggests it a adequate depth cues and visual feedback. We therefore sought to examine the effect of

Previous work in sketch-based modeling uses rendered adequacy. However, it leads to a high chance of poor design tasks. Designers expressed interest in switching back at \(\pi/2\) and \(3\pi/2\) radians was also seen for curvature. This similar to another local maximum exists around \(3\pi/2\) radians. A

Visual Trends with respect to depth deviation: the maximum depth visual guidance, similar to Viviani and Terzuolo's \([38]\) observation much smaller than the tenfold difference they found.

"Guides" feature in Tilt Brush \([43]\), which snaps strokes to grids and scaffolding curves, can help to position strokes of two characteristic jumps more accurately, increasing accuracy by 17% and 57%, mobility, the latter may be preferable in long design sessions projecting to virtual planes in VR. Thus, these results could apply to a wide utilization for estimating user precision in performing 3D VR-sketching experience. It is possible that mid-air drawing to aesthetically poor strokes. It should be noted that our results characterize strokes drawn by amateurs with no prior in traditional sketching,

CO, CHI 2017, USA
Figure 5. Post-processed results. HoloLens hardware limitations restrict us to basic Gouraud shading. With appropriate shading and occlusion, SymbiosisSketch designs can seamlessly blend into the real world. (Clockwise from top) war helicopter shooting at Captain America (Figure 14a), mechanical wing augmentation (Figure 14c), mini car (participant creation), Flintstones’ house (author creation), and large fan (Figure 14d).

SYSTEM OVERVIEW AND SETUP

Our system requires three main hardware components: an AR-capable Head-Mounted Display (HMD), a tablet for 2D drawing, and a digital pen with 6-degree of freedom (DoF) motion tracking to draw mid-air, as well as on the tablet. The pen position and orientation is tracked using Vicon motion capture cameras. The three devices communicate in real-time to ensure a unified, consistent, state of the world and the design elements. We used the Microsoft HoloLens as our AR HMD, whose spatial mapping capability gives us a coarse 3D map of the physical world as a triangle mesh. The tablet for 2D interface is a Microsoft Surface Book clipboard, detached from its keyboard.

Metaphorically, our setup is analogous to a painter’s bimanual interaction with her tools. Typically, a painter reserves her dominant hand for holding the paintbrush for making marks on the canvas, and the non-dominant hand to hold the color palette. In our multimodal interaction system, the user holds the pen in the dominant hand, while the tablet is typically held in the non-dominant hand (but can also rest on a table like an easel). The tablet serves two purposes. First, it renders an orthographic view of the world, and users can draw on the tablet to project their strokes to a 2D canvas visible from this orthographic window (Figure 6a). Second, it also includes a function toolbar, accessible with pen or touch input (Figure 8). For a given drawing canvas planar projected on the tablet screen, the position of the orthographic camera remains fixed for comfortable sketching, regardless of the position and orientation of the tablet. Hence, we do not need to explicitly track the position and orientation of the tablet.

In our prototype, we use the buttons on a standard mouse to trigger these interactions. The mouse is magnetically fastened to the back of the tablet, allowing the user to interact with the mouse while holding the tablet (see Figure 6b). Alternatively, the user can also hold the mouse by itself in the non-dominant hand, while the tablet rests on a table.
Literature


Literature


