Desk Console: Augmenting 3D Virtual Controls on Physical Desks for Immersive Authoring

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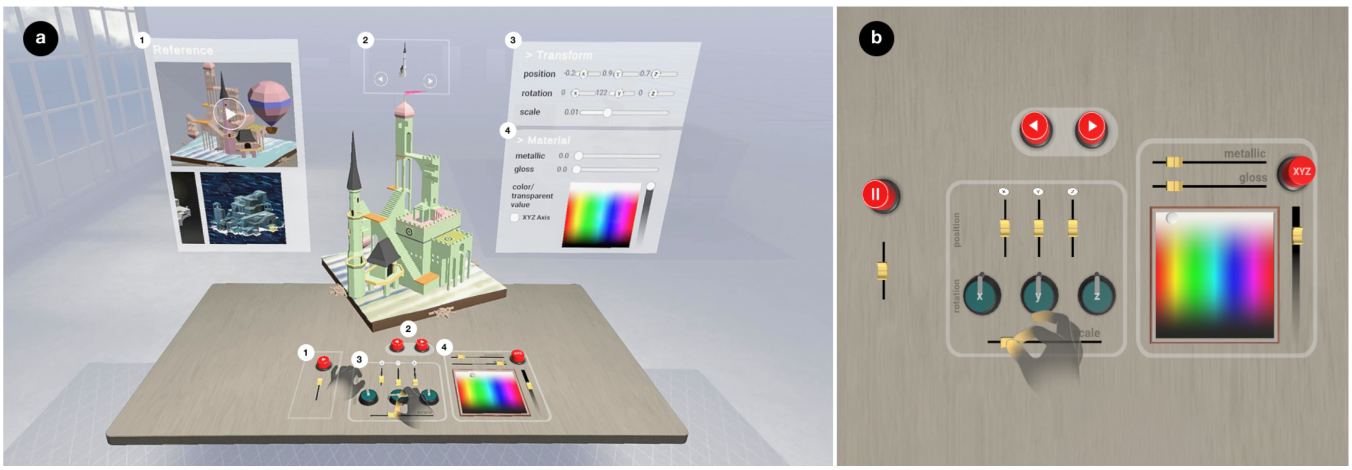

Figure 1: Desk Console Interface for Immersive Authoring. (a) Desk Console enhances control panel interaction by integrating 3D virtual controls onto a physical desk. Numbers 1–4 correspond to specific panels and their associated controls. (b) Close-up view of the controls, designed for bare-hand interaction with passive haptic feedback.

Abstract

Immersive authoring provides a powerful 3D content creation experience in virtual reality (VR) by freeing users from the tedious loop of desktop editing and VR validation. However, complex control panels required for creative tasks often disrupt immersion with awkward or unstable spatial interactions. To address this, we present Desk Console, an authoring interface that transforms 2D control panels into virtual 3D controls on a physical desk, enabling tangible spatial interaction similar to real-world interactions. Desk Console transforms traditional control panels into 3D representations based on input types and provides passive haptic feedback through the desk's physical surface. We demonstrate Desk Console's capabilities through an interactive 3D scene design application.

CCS Concepts

• **Human-centered computing** → **Interaction techniques**.

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Keywords

Virtual Reality, Mixed Reality, Immersive Authoring, Passive Haptic, Interaction Design

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1 Introduction and Related Works

The proliferation of virtual and augmented reality (VR/AR) technologies is driving an increase in 3D content creation. Authoring 3D content on traditional 2D desktop setups often requires repeatedly donning and removing a head-mounted display (HMD), resulting in a cumbersome workflow. This challenge drives demand for immersive authoring interfaces [10] that provide immediate feedback within virtual environments. However, complex graphical controls inherent to creative tasks, such as inspector windows and control panels, can hinder spatial interaction and limit creativity.

Efforts to simplify complex control systems have explored various interaction methods. Device-based authoring tools, such as mice [14] and controllers [18], [19], offer stability but compromise portability and disrupt immersion with less natural interactions

([12], [13]). Gesture-based interfaces [3], [9], which enhance immersion by freeing the user's hands, are expressive and natural but may cause hand fatigue and low learnability as they differ significantly from traditional graphical user interfaces (GUIs).

To achieve both stable and natural interaction with control panels, Desk Console employs 3D transformation strategies. Prior research ([11], [17]) shows that 3D representations enhance intuitive control over 2D inputs. Additionally, space-multiplexed inputs [7], where controls are distributed spatially, reduce cognitive load and support more efficient cognitive-motor strategies [2] than time-multiplexed systems like mice and controllers [6]. Building on these findings, Desk Console incorporates 3D manipulation for cognitive-motor strategies in immersive authoring.

This demo introduces Desk Console, an immersive authoring interface that transforms complex control panel interactions into intuitive 3D manipulations for stable and expressive workflows. Desk Console converts traditional 2D panels into 3D representations on a physical desk, enabling intuitive and tangible spatial interactions with tactile feedback, closely resembling real-world interactions (Figure 1). We classify common control panel elements and detail the design and implementation of their corresponding 3D controls. Finally, we demonstrate the interface's adaptability and utility with an interactive scene design application.

2 Desk Console Interface

Desk Console is an immersive authoring interface that transforms 2D control panels into 3D virtual controls on a physical desk, enabling spatial interaction similar to a sound mixing console or cockpit. We aimed to design an interface that converts complex traditional GUI panel interactions into tangible spatial manipulation. To achieve tangibility, the physical desk was integrated as an interaction surface, leveraging Substitutional Reality [15] and Annexing Reality [8] concepts, which merge physical objects with virtual environments to create tactile experiences. This design provides operational stability through passive haptic feedback from the desk surface while enabling intuitive 3D interactions with spatially distributed controls. By combining stability and intuitive interaction, Desk Console encourages creativity by allowing users to explore a wider range of design possibilities.

2.1 Virtual 3D Control Design Mapped from 2D Panels

To ensure flexibility and adaptability, we categorized common control panel input types and mapped them to corresponding 3D controls. We analyzed interfaces from widely used creative tools like Adobe Creative Suite [1] and 3D scene editors such as Unity [16] and Unreal [5]. As shown in Figure 2, UI elements were classified by input dimensions [4] into three primary types: Binary Input (0D), Value Input (1D), and Navigation Input (2D). While this classification does not encompass all possible UI controls, it aims to generalize the most common elements for a flexible and scalable design.

Based on this input resolution, Desk Console employs three types of virtual 3D controls: buttons, sliders, rotary knobs, and pin on frame as illustrated in Figure 2.

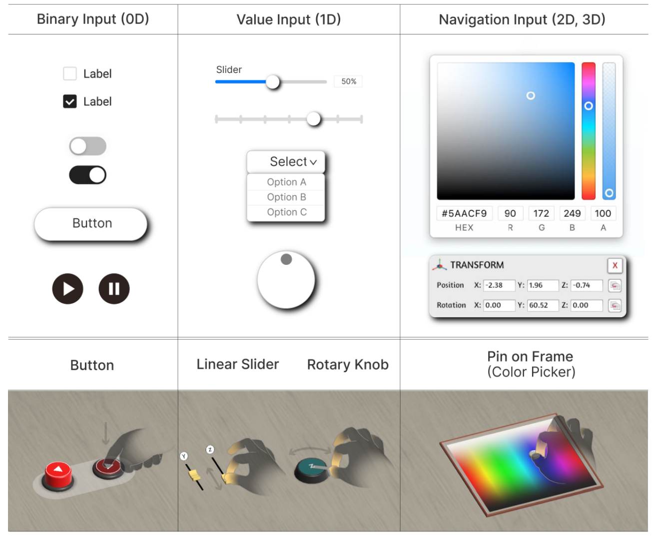

Figure 2: 3D Represented Controls Mapped from Categorized UI Input Types

Button for Binary Input (0D): This input type includes mutually exclusive interactions, such as toggle buttons and checkboxes. In Desk Console, binary inputs are represented as physical buttons that users can press or tap with their hands. The button's surface aligns with the physical desk, providing passive haptic feedback when pressed. In the example shown in Figure 1, buttons are used for actions like play/pause and enable/disable. The button's graphical state dynamically updates to visually indicate its status.

Slider for Value Input (1D): This category covers controls for adjusting values along a linear axis, such as sliders and dials. These are transformed into slider- and knob-like controls similar to those found on audio mixers. Users interact with these controls by sliding back and forth or rotating their fingertips on the desk surface using pinching gestures. Figure 1 illustrates examples of vertical and horizontal sliders for finite value input and a rotary knob for infinite value input.

Pin on Frame for Navigation Input (2D): A common example of 2D input is a color picker, where users select colors from a palette. Desk Console represents this navigation input as a pin elevated on a small frame. Similar to sliders, users use pinching gestures to explore the frame while feeling the haptic feedback of the desk surface beneath their hands.

These controls are designed to preserve familiarity of traditional UI patterns while reflecting the physicality and behavior of real-world objects, enabling users to intuitively understand their functionality. The interactions leverage instinctive actions, allowing users to operate controls with minimal visual attention and focus on tasks. By aligning the controls with the desk surface, the design provides eyes-free haptic feedback. Additionally, the controls enhance user confidence and engagement by providing audio feedback, such as sounds resembling their real-world counterparts (e.g., button clicks), and visual cues, like fingertip color changes during interaction.

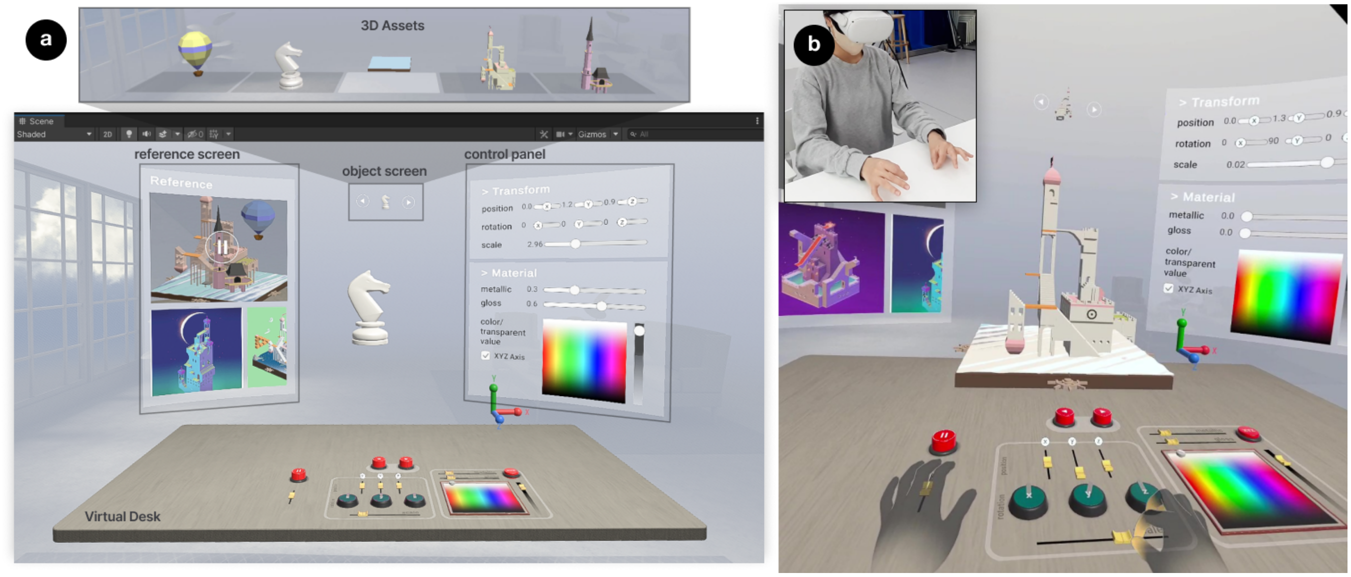

Figure 3: Desk Console Interactive Application. (a) Application composition, including the Reference Screen, Object Screen, and control panels. (b) User's VR first-person view with real-world interaction

2.2 Implementation

The Desk Console interface was implemented in a VR environment to systematically control settings and variables. The Oculus Quest 2, equipped with an integrated camera for real-time hand tracking, was used as the VR head-mounted display. The software was built using the Unity Game Engine (version 2020.3.33f1) and utilized the Oculus Interaction SDK (version 49.0) for hand tracking and interaction.

The workspace employed the minimalist Room environment provided by the Oculus SDK to minimize distractions and enhance focus. To account for individual differences in seated height, a calibration process aligns the virtual desk asset with the physical desk. Users pinch both hands at the edges of the physical desk, and their hand-tracked z-coordinates are used to align the virtual desk to the physical surface. Controls requiring direct manipulation were placed within a reachable range of 50–70 cm, while screens and content were positioned approximately 1 meter away to optimize visibility.

Each control was developed for intuitive operation, ensuring users' fingertips make contact with the desk surface during interaction. Buttons use Poke Interactions, while Sliders, Knobs, and the Pin on Frame employ Grabbable function triggered by pinching gestures. Sliders and the Pin on Frame implement movement via the Translate Transformer, while the Knob supports rotation through the Rotate Transformer. For color selection, the pin on the frame casts an invisible ray toward the color palette, retrieving texture information at the ray's contact point to identify the selected color.

3 Interactive Application

To evaluate the usability and adaptability of Desk Console as an immersive authoring interface, we applied it to a 3D scene design task requiring frequent adjustments to object properties and repeated control panel interactions in a virtual environment.

Interface Composition. For general applicability, the control panel was positioned on the right side of the content, mirroring the typical interface layout of 3D authoring tools like Unity and Unreal, as shown in Figure 3. Based on common scene-building workflows, the interface featured a Transform Panel for adjusting position (x, y, z), rotation (x, y, z), and scale, as well as a Material Panel for modifying metallic, gloss, transparency, and color properties. Further, a toggle button was provided to display a 3D coordinate grid for easier spatial reference. To support the design workflow, a Reference Screen was included, providing access to example videos and concept art for inspiration. Object Screen above the 3D content area enabled users to browse and add assets. Users could modify the currently displayed asset via the control panel and switch between assets using the left and right arrow buttons. The 3D assets, shown in Figure 3, were chosen to foster creative exploration of different moods and spatial arrangements, including abstract castles hot air balloons, and chess pieces.

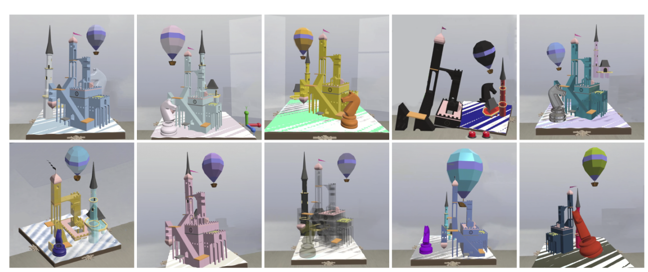

Figure 4: Examples of Personalized 3D Scenes Created with Desk Console

Interaction Flow. First, users pinch both hands at the desk's edges to align the virtual desk with the physical desk. Once calibrated, users can interact with virtual controls aligned to the desk surface to browse reference materials, adjust asset properties, and customize visual elements. By combining the properties of provided assets, users can create personalized 3D scenes within the virtual environment, as demonstrated in Figure 4.

4 Conclusion

We present Desk Console, an immersive authoring interface that transforms traditional control panels into virtual 3D controls on the physical surface of a desk. Complex graphical controls inherent to creative tasks, which often hinder interaction, are typically managed with controllers or mid-air gestures, compromising naturalness or stability. Desk Console addresses these challenges by classifying 2D-panel elements based on input patterns and augmenting them as 3D representations on a physical desk. This design enables spatial interaction with passive haptic feedback, capturing stable and intuitive workflows. Through an interactive scene design application, we demonstrate how 3D-transformed control panel interactions support cognitive-motor strategies and foster creative exploration.

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