Multi-User Framework for Collaboration and Co-Creation in Virtual Reality

Scott W. Greenwald, MIT Media Lab, scottgwald@media.mit.edu
Wiley Corning, MIT Media Lab, wileycorning@gmail.com
Pattie Maes, MIT Media Lab, pattie@media.mit.edu

Abstract: We present CocoVerse, a shared immersive virtual reality environment in which users interact with each other and create and manipulate virtual objects using a set of hand-based tools. Simple, intuitive interfaces make the application easy to use, and its flexible toolset facilitates constructivist and exploratory learning. The modular design of the system allows it to be easily customized for new room-scale applications.

Keywords: virtual reality, remote collaboration, collaborative learning

Introduction and motivation

While the potential of multi-user immersive virtual reality to facilitate collaborative learning is well-established, few research applications currently exist in this field. As part of our initial research, we have developed an application, called CocoVerse, that provides a broad set of creative affordances to users in a shared virtual space. Here we describe the design of this application, its utility for communication, and the educational use cases it supports. We also present useful insights on VR interface design that have arisen from preliminary user testing.

CocoVerse is intended to serve as a platform for collaborative experiences in VR. The suite of functionality within this application provides users with the capability for both primary content authorship and interaction with pre-existing environments. Starting in a shared virtual space, users can sketch volumetric surfaces in 3D with a virtual paintbrush; create and manipulate objects; capture images with a camera, and place them as pictures; and write phrases using a speech-to-text system. These affordances effectively provide a 3D whiteboard for teaching and learning. The interaction primitives we provide relate consistently to one another; for example, falling objects will rest on painted surfaces, and any user-created element can be moved or erased. This consistency ensures that users' actions produce logical results, helping to build a strong sense of presence. The sense of immersion in the virtual space is further enhanced when users are also present in a shared physical space (Beck et al., 2013).

Real-time co-creation in VR enables a broad set of educational interactions. Teachers can develop and present 3D content to students. Users can learn by interacting with dynamic systems, or by exploring and annotating environments, models and datasets. Our modular architecture can serve as a base for domain-specific experiences. Since all of these interactions are fully realized in the virtual space, they can be recorded and played back in full for immediate or later review.

Design and Implementation

Our application utilizes the HTC Vive, which incorporates a head-mounted display and two handheld controllers. All three devices utilize a tracking system which maps the user's physical movements onto a room-scale virtual space with six degrees of freedom.

Virtual reality imposes particular constraints on user interface design. As discussed by Sutcliffe and Kaur (2000), users must be able to locate and recognize the conceptual objects required to carry out tasks; the objects themselves should provide cues as to their utility. We fulfill these requirements by providing users with discrete one-handed *tools*, each of which encapsulates a particular set of affordances and can be assigned to an individual controller. Tools are accessed via a virtual toolbelt positioned at the user's waist level. Once users are aware of the toolbelt's position, they are able to operate it in a hands-free fashion, thereby leveraging the spatial nature of the VR interface. This interaction model helps users to quickly explore the range of capabilities available to them, and to mix and match their active abilities, such as a brush and an eraser, to effectively carry out compound tasks.

Each tool instance is explicitly associated to the position and input of a specific handheld controller, helping users to compartmentalize their interactions. Some tools also open interfaces that are spatially bound to the opposite controller; for example, selecting a paint brush tool with the left hand produces a color palette on the right hand, which allows the user to change their paint color by dipping their brush into one of the colors on the palette.

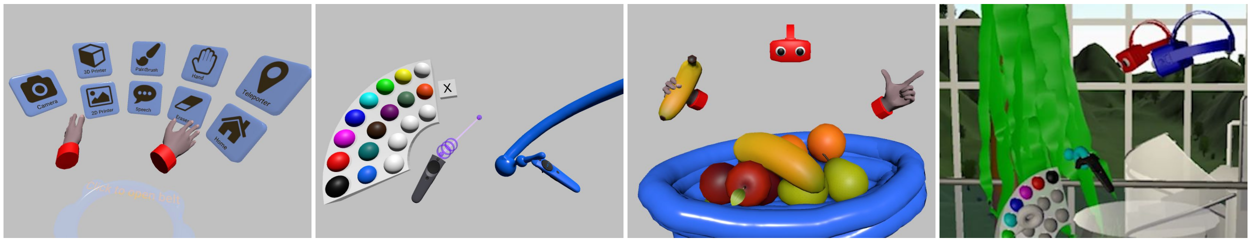

Figure 1. The toolbelt system; example of different tools; user with created objects; multiple users in environment.

Many tools can be adjusted to produce actions at different distances from the controller. For example, when using the paintbrush, users can choose to draw at one of a range of fixed distances from the controller, or to draw directly onto surfaces in their surroundings. After using the distance settings, some participants have remarked positively on them for adding accessibility to users of different physical sizes and arm lengths. Haptic feedback is provided when moving a tool's reticle across a surface, allowing users to remotely "feel" virtual objects. Users are capable of moving large distances using *teleportation*, in which the user is instantly transported to a new position in the virtual environment. Because teleportation appears as a transition between distinct still frames, the user does not experience vection and is unlikely to suffer motion sickness (McCauley and Sharkey, 1992).

Initial evaluation

We performed a series of informal trials in which the application was made available to participants at an event for VR enthusiasts. Users were introduced to the system in pairs, provided with verbal instructions, and left to explore freely for approximately ten minutes. Roughly 30 people tried the program; participants were self-selected and represented a broad range of VR experience levels. The entire three-hour session was recorded both with screen capture of the virtual environment and video recording of the physical environment.

This rapid-introduction process generated a number of insights related to our interface design. To open the toolbelt, users were instructed to position a controller inside the belt model and briefly press the trigger, as one would perform a mouse click. Many users had difficulty learning this interaction, suggesting that the controller was not seen as directly analogous to a mouse. Some users also had difficulty intersecting the controller model with buttons in the virtual environment, indicating that additional visual feedback was necessary to supplement their depth perception. Once users became accustomed to accessing the provided tools, they were able to navigate the environment and perform tasks with great fluidity. The degree of interaction between pairs of users varied; while some users performed tasks independently, others collaborated and used the tools to interact with one another.

Conclusions and future work

The CocoVerse application shows great promise as an engine for learning and creativity. At a time when VR lacks a set of canonical interface elements, such as the pinch-to-zoom functionality that is now ubiquitous in mobile applications, our tool-based interaction model and toolbelt are contributions that demonstrate robustness and extensibility. As the current feature set is polished, we intend to develop specific educational use cases, characterize the needs of collaborative teaching and learning, and offer appropriate design guidelines.

Selected references

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