VilmReel: Scrollable Multi-Environment VR with Cross-VE Notifications

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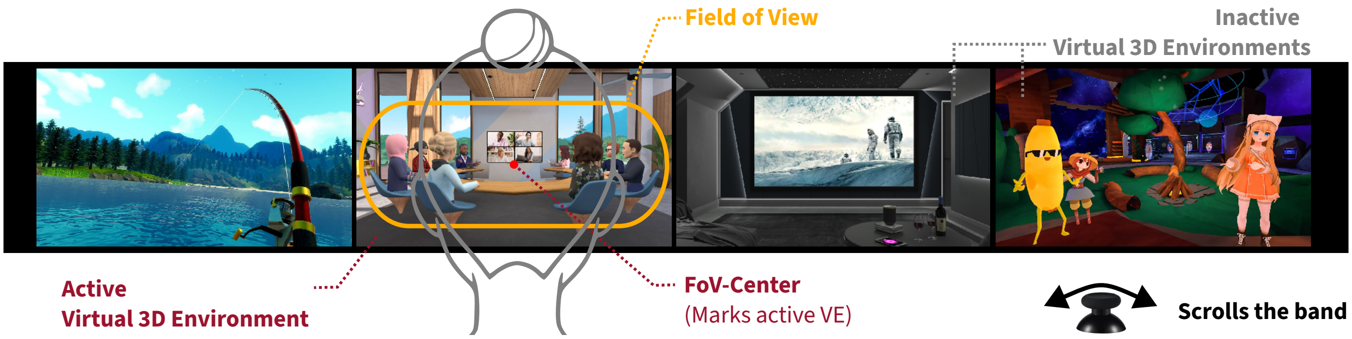

Figure 1: VilmReel arranges multiple VEs along a horizontal band that moves with the user's head, maintaining immersion while enabling: (a) continuous band scrolling via thumbstick to switch the active VE; (b) spatial audio cues communicating event type and 3D position across all VEs, with glitch-modified sound distinguishing non-active VE events; and (c) directional haptic pulses guiding users to event-containing VEs.

Abstract

Current VR interfaces impose a single-environment constraint, creating significant barriers for tasks requiring concurrent awareness and manipulation across multiple virtual 3D environments (VEs). We present VilmReel, a VR interface that enables interaction across multiple VEs through a scrollable band interface. The interface resembles a film reel, but with each frame showing a stereoscopic VE instead of an image. Users can scroll the band horizontally, maintaining spatial awareness of all environments. Moreover, we propose multi-modal event notifications: spatial audio informs the user of the location and type of an event in an arbitrary VE (e.g., a person speaking or an in-game sound effect). If the event is not in the active VE, a sound effect is added to indicate that the event happened in another VE and directional vibrations guide the user to the corresponding VE. Finally, we detail on lessons-learned designing the system, including various sound effects and visualizations.

CCS Concepts

• **Human-centered computing** → **Virtual reality**.

Keywords

Virtual Reality, Multi-Environment Interaction, Multitasking

1 Introduction

Virtual reality has evolved beyond single-purpose applications into a platform for diverse, concurrent activities. Users increasingly need to maintain presence across multiple virtual environments (VEs) simultaneously. For example, moderators overseeing game servers need to stay informed about what is happening in different areas of the game, operators monitoring remote facilities want to quickly check for changes in a facility, or individuals balancing professional workspaces with their personal life (e.g., social VR communities and casual games). Yet most current VR interfaces impose a single-VE constraint, requiring users to exit their current context, navigate launcher menus, and reload entirely new applications to switch between VEs. This paradigm treats multi-VE access as exceptional rather than fundamental, creating significant barriers for workflows requiring concurrent awareness and rapid context switching.

Prior research address multi-VE access by linking environments via portal-like artifacts [1, 19], routing navigation through a central hub [11], or blending multiple VEs into a unified view [6, 18]. However, these approaches typically require in-world linking artifacts, introduce additional steps for switching, or sacrifice clear separation between VEs.

We present VilmReel, a novel VR interface that supports multi-VE interaction by introducing a quick and fluid technique to switch between VEs. Inspired by film reels, VilmReel arranges VEs along a

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horizontal scrollable band where each frame contains a fully immersive stereoscopic environment. Within each frame, all standard VR input (head and body movement, hand and controller interaction) functions as users expect in conventional single-environment VR. Users navigate the band via controller thumbstick, fluidly transitioning between immersive full-screen and split-screen configurations. Moreover, VilmReel introduces a multi-modal notification system combining spatial audio and directional haptic feedback to communicate event type, precise 3D position, and source VE. This enables situational awareness across all VEs without constant visual monitoring.

In summary, this work contributes:

(1) *VilmReel, a novel VR interface* for visualizing and interacting with multiple VEs, based on a film reel metaphor. Continuous thumbstick scrolling transitions fluidly between full-screen and split-screen configurations.
(2) A *cross-VE event notification system* that combines spatial audio and directional haptics to communicate the event location, event type, and the VE the event is occurring.
(3) *Lessons learned* regarding the visualization and interaction with multi-VE systems and the use of audio effects to differentiate events based on their VE.

2 User Story: Multi-Application Multitasking

Alex juggles four VR applications simultaneously using VilmReel. She's working in a virtual office (active VE), reviewing the company's latest 3D product mockups, while maintaining presence in VRChat with friends, monitoring a casual fishing game, and keeping her virtual home space accessible. Mid-review, two pulses vibrate her right controller. She hears her friend Jamie's voice with a glitch effect, spatially positioned to her left. The modified audio tells her it's not a colleague speaking; Jamie needs her attention at the virtual cafe table in VRChat. Swiftly, Alex pauses her work and scrolls VilmReel two VEs to the right. During the app switching, Alex positions herself to look into the direction where the voice came from and directly looks towards Jamie. He asks a quick question about weekend plans. Alex responds, slides back to the office, and resumes her review. Single pulse, left controller. A fish just bit in her fishing game. Alex recognizes the distinctive splash of a rare fish bite in her fishing game. A quick scrolling of VilmReel to the left and she reels it in, then returns to work. Throughout her workday, Alex stays connected across social, leisure, and professional contexts without tedious launcher navigation or anxious notification checking.

3 Related Work

VilmReel is inspired by and relates to prior work on multi-VE interaction and VR notifications:

3.1 Experiencing Multiple 3D Environments

Switching between virtual environments is essential in task transitions [9], collaborative workflows [5], and multi-protagonist experiences [4]. Existing approaches employ transitions, portals, environment blending or split-screens to enable multi-VE access.

Transitions provide discrete mechanisms for moving between VEs. Oberdörfer et al. [15] compared transition techniques, finding simulated blink most effective. Feld et al. [7] found users prefer brief, efficient transitions.

Portals serve as spatial connectors between environments. Recent work extends basic portal interactions: Ablett et al. [1] enable reaching through portals. Poros [16] investigates configurable proxy spaces that mirror a marked distant region into a nearby, manipulable volume, enabling users to interact with multiple distant spaces from within reach. Slice of Light [19] introduces translucent "slices" that let users preview activity in other users' VEs and step through a selected slice to transition into that VE, supporting transparent and integrative travel among multiple realities. Off-The-Shelf [12] explores see-through "masks" that display live previews of different VEs and let users teleport into a selected VE by bringing the corresponding mask to the face. Instead of placing portal-objects into VEs, SliVR [11] introduces a 360° hub with portals to 6–12 VEs for fast target selection and VE switching. In contrast, VilmReel arranges the VEs on a head-attached band, enabling scrolling through the VEs on demand without requiring a portal link or additional hub environment.

Alternative approaches *blend multiple environments* into unified spaces. OVRlap [18] overlays transparent layers of different VE perspectives; Cools et al. [6] introduced "Blended Spaces" that integrate objects from various environments. While blending enables simultaneous multi-VE experience, it sacrifices spatial clarity. Overlapping content can obscure individual environment contexts and the blended scenes might become visually overloaded.

Similar to desktop and mobile systems, *split-screens* can be used to interact with two or more VEs in VR. MultiSoma [13] uses split-view visualization for multiple virtual bodies in a shared virtual space. ParaSight [20] shows two VEs, one for each eye, and compared this approach to a split-screen configuration. They found that ParaSight led to higher presence and higher task efficiency, but increased eye strain and cybersickness. Unlike traditional split-screen approaches, CheckerVision [10] renders two VEs simultaneously by interleaving them in a checkerboard grid layout. VilmReel supports fluid switching between full-screen and traditional split-screen configurations by either stopping the band on one VE or between two.

3.2 Notifications in XR

Notifications in XR must balance noticeability and interruptibility, and should be distinguishable from events occurring within the virtual scene. NotifiVR [8] provides a systematic investigation of VR notification modalities. The paper reports that auditory and multimodal cues can improve noticeability compared to purely visual designs. They further emphasize that notifications for external events should be distinguishable by design to avoid confusion with in-world stimuli. VilmReel follows this principle by prioritizing spatial audio and haptic cues over visual pop-ups. Importantly, our haptics encode an event's *VE location on the band* to avoid the challenge that the controllers position in the VE is often not visible [8]. We also add an explicit audio effect on top of the original event sound to disambiguate events originating in inactive VEs.

Beyond modality, prior work explores notification placement and adaptivity. Rzayev et al. [17] compared head-up, on-body, floating, and in-situ placement of text notifications, showing that placement meaningfully affects perception and preference. Zenner et al. [21] propose an *Immersive Notification Framework* that adapts notification presentation to the user's current situation and message priority, aiming to preserve immersion compared to generic in-VR pop-ups. Cho et al. [3] evaluate nine audio-visual message notification designs in XR. Results suggest that users want notification modality and presentation to vary with message content and context. Consistent with this direction, VilmReel avoids generic pop-ups and instead delivers cross-VE event feedback through event-specific spatial audio.

Finally, while prior audio work in XR often aims to increase plausibility (e.g., matching environmental acoustics) [2], VilmReel intentionally trades plausibility for discriminability by adding audio effects that signal an event is occurring in a different VE.

4 VilmReel

VilmReel contributes a novel band layout to experience and interact with multiple VEs with cross-VE notifications.

4.1 Scrollable Multi-Environment VR

VilmReel enables simultaneous access to multiple VEs through a horizontally scrollable band interface that positions environments in a spatial continuum (see Figure 1). This is analogous to a film strip where each frame contains a fully immersive stereoscopic environment rather than a static image. Unlike traditional VR systems that isolate users within a single environment, the band architecture arranges VEs side-by-side, allowing for fluid navigation.

Users navigate VilmReel by moving the band horizontally using the right controller thumbstick, smoothly scrolling environments left or right to bring different VEs into view (see Figure 2). The size of each VE frame on the band is big enough to cover the user's complete field-of-view and hence allows the user to be fully immersed in a single environment. However, the band can also be stopped in-between two VEs, to enable split-screen configurations (see right side of Figure 2).

4.2 Cross-VE Notifications

A key capability of VilmReel is multi-modal event notification across VEs, enabling users to maintain situational awareness without constant visual monitoring. The system employs complementary directional haptic and spatial audio feedback to communicate which VE contains an event and where within that VE it occurs.

4.2.1 Haptic Feedback: Directional VE Identification. Controller vibration indicates the *location on the VilmReel band of the event-containing VE* relative to the currently active VE (centered in the user's field of view). The controller maps the direction of the VE: right controller vibration signals an event to the right; left controller signals left. Pulse count encodes the distance (i.e., number of VEs to the left/right). For example, two pulses on the right controller indicate an event two VEs to the right. Events in the active VE trigger no vibration, as visual attention is already directed there.

4.2.2 Spatial Audio: In-VE Event Localization. Spatialized sound communicates the *event type and its position within the VE*. The event sound is played across all environments regardless of which VE the user currently views. For events in the active VE, audio plays from the true 3D event location using standard spatial audio rendering. For events in the other VEs, the system plays glitch noises as an audio effect on-top of the original event sound. The glitch effect marks the sound as originating from an inactive VE while preserving its spatial position within that environment. We found the glitch effect to be easily distinguishable and compatible with diverse event sounds.

Together, the haptic feedback and spatial audio enable users to simultaneously identify both the source VE (via haptic) and the precise event location (via spatial audio).

5 Implementation

The VR system was developed using Unity 6.3 for the Meta Quest 3. All VEs are included in the same scene on top of each other, but separated in different layers. The top object of each VE contains a script that contains its stencil id (unique for each VE) and a background sound, which is played when the VE is active. Each VE contains its own sky-box. The layers for the VE were excluded from the default rendering pipeline to be only rendered through a stencil shader.

The prototype implementation contains 4 VEs. For the VEs we chose free scenes from the Unity Asset Store that resemble a set of diverse 3D environments, such as an industrial complex, a city crossing, a lodge, and a castle. A VilmReel script manages multiple VEs through an array and creates a new Quad-GameObject for each VE on the band, assigning a material with the corresponding stencil shader. These objects are children of the users head-object in the XR Rig to stay stable in the users view (i.e., automatically move and rotate with the head). The distance between the Quads and the eyes were 60 cm.

After 3 s to 10 s a study script spawns a new target at a random VE in a random direction [0-360°]. The target stays active for 10 s. After the target despawns a new target-timer is started. User movement was disabled to ensure that the target is not spawning behind objects.

For the controller vibrations, we chose the pulse parameters of using 100 ms pulses separated by 100 ms intervals. These parameters were empirically tuned for Meta Quest 3 controllers to provide a fast feedback while maintaining a clear separation of pulses.

6 Lessons Learned

VilmReel was developed in an iterative design process. This section briefly describes prior iterations and their shortcomings to help future research to avoid the same mistakes:

We evaluated three *band configurations*: horizontal, vertical, and a circular loop surrounding the user. The vertical band, which split the field of view top-to-bottom, proved less effective than the horizontal arrangement. A horizontal split-screen configuration seemed more practical and horizontal scrolling allowed for a better mapping of haptics on the left/right controller. The circular loop configuration wrapped the VEs 360° around the user. Instead of sliding the band, the thumbstick rotated the loop around the user's head. However, this continuity introduced navigational ambiguity: the optimal path to a given VE changed depending on the current active VE. For example, in a four-VE system (VE1–VE4 arranged in a loop), VE1 could be reached by swiping left from VE2 or by

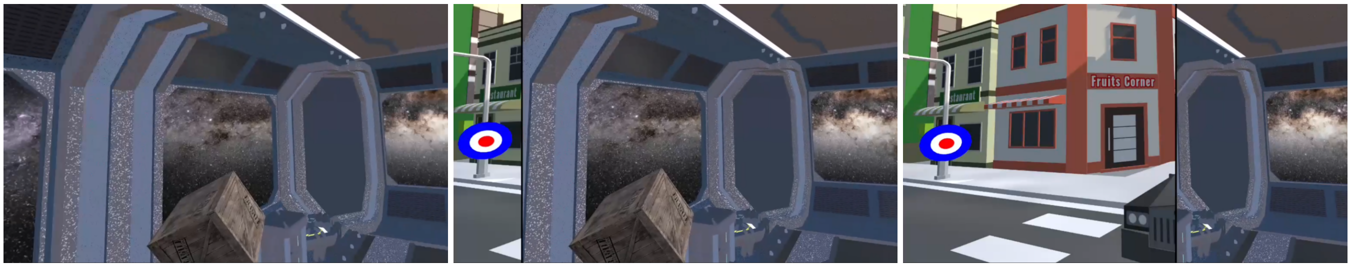

Figure 2: (Left) While interacting full-screen in a 3D space station environment, the user hears a glitch-modified sound from the front-left and feels a single vibration pulse on the left controller, indicating an event one VE to the left. (Center) The user scrolls the band leftward using the controller thumbstick. (Right) The event source (target object) and its city environment context become visible. The user can interact with the target while maintaining awareness of both 3D environments in a split-screen configuration.

swiping right from VE4. While this wraparound provided shortcuts, it eliminated consistent directional relationships and destroyed the clear linear ordering. For the circular loop, we also explored an alternative scrolling technique in which users held a button and rotated their head to rotate the band (similar to a 360° hub [11]). While this head-driven navigation felt more natural than thumbstick scrolling, the continuously changing the view direction made it harder to stay oriented within the VEs.

Our initial *notification design* assigned a unique audio effect to each VE, attempting to encode both event location and source environment simultaneously. We implemented eight distinct effects: chorus, echo, pitch shift, reverb, telephone narrowband, radio narrowband, distortion, and glitch. This approach revealed two fundamental limitations. First, effect perceptibility varied dramatically across event sound types. For example, pitch shift was easily noticeable on speech but nearly imperceptible on sounds like sirens or alarms. Narrowbands only worked well for audio covering frequencies outside their spectrum. We found that additive sound effects (like glitch) worked best for most types of sounds. Second, the cognitive load of maintaining effect-to-VE mappings proved prohibitive. Users needed to learn and recall which audio effect corresponded to which VE. This memorization task resulted in misidentification and slow response times. Hence, we simplified the system by using a binary distinction: unmodified audio for active-VE events, glitch effect for all inactive VEs. This reduced the audio system's role to answering "here or somewhere else" while haptic pulse patterns communicated the precise VE identity.

7 Limitations

VilmReel targets the common case of 3–5 concurrent environments, comparable to multitasking in desktop and mobile contexts. The current haptic pulse-count encoding works well within this range but would become cognitively demanding at larger scales. Preliminary informal testing suggests that multi-modal feedback enables users to quickly locate events across up to five VEs after a short learning period. A formal user study is needed to rigorously evaluate system performance, detection accuracy, and behavioral effects.

On the technical side, the prototype of VilmReel requires all VEs to be present in the same scene. While this is suitable for multitasking in one VR application (e.g., a specific monitoring application), it prevents the system from multitasking within different applications. This requires a deeper integration into the VR operating system. Such a system would also need a way to add, rearrange, and delete VEs from the band.

An auditive sound is required to find the event location inside the environment. Events that do not create a sound cannot be localized inside the environment. In the future, we plan to investigate visual cues to guide the user to find the event location inside a VE. Finally, the events in our implementation are automatically triggered at random time intervals. For VEs these events would be triggered by the application logic (e.g., game events or digital twin simulations). For remote physical environments, the application needs to include automatic event or anomaly detection (cf. [14]).

8 Conclusion

We presented VilmReel, a VR interface that enables simultaneous multi-environment interaction through a scrollable band. We detailed a cross-VE notification system that informs users about audio events across multiple 3D environments. Our design exploration revealed that binary audio distinction (active vs. inactive VE) combined with directional haptic guidance provides clear and effective event notifications, communicating event type, precise 3D location, and source VE simultaneously. Compared to prior solutions that rely on abstract application launchers and 2D overlays, VilmReel maintains spatial locations of the events without breaking immersion or forcing users to mentally map between 3D spaces and 2D abstractions. We hope this system and the detailed lessons learned will spark further research in multi-VE interaction and VR notification systems.

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