Towards Asynchronous Hybrid User Interfaces for Cross-Reality Interaction

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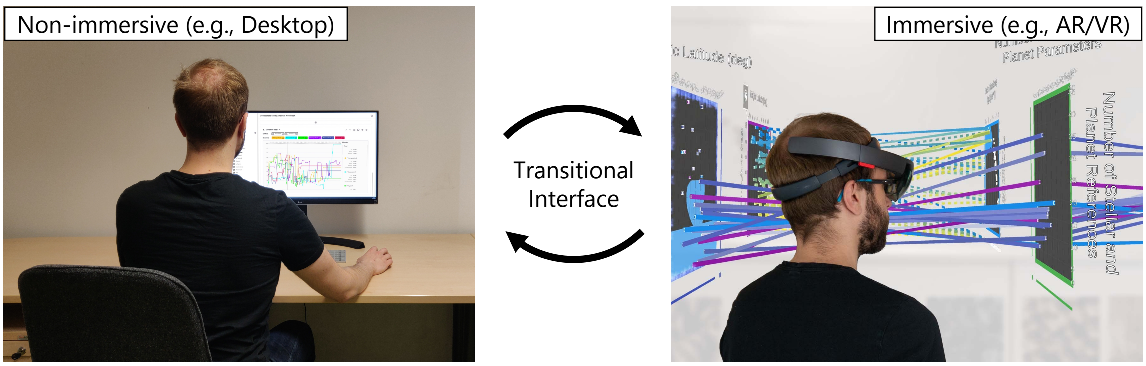

Fig. 1. A possible example scenario for asynchronous hybrid user interfaces: Users may start their analysis with an overview of aggregated 2D visualizations on the desktop (left), then switch to an immersive environment to make use of the stereoscopic view or investigate the data within its environmental context (right), and then switch back to the desktop to statistically validate their findings (left).

Hybrid user interfaces combine cross-reality devices (e. g., head-mounted display) with other heterogeneous device technologies (e. g., smartphone) to compensate for the disadvantages of one device with the advantages of the other, such as addressing the lack of haptic feedback in mid-air interaction with touchscreen input. Such hybrid user interfaces typically involve the synchronous use of multiple input and output technologies. In this work, we instead consider the *asynchronous* use of heterogeneous devices (e. g., using a desktop and virtual reality device in sequence). While the sequential use of different technologies does not necessarily offset the individual device-specific disadvantages, it allows users to choose the more appropriate device for a particular sub-task. In this context, transitional interfaces play an essential role in enabling the switch between devices, while allowing the user to maintain a mental connection between realities and seamlessly continue with their task where they left off.

CCS Concepts: • **Human-centered computing** → **Virtual reality**; **Mixed / augmented reality**.

Additional Key Words and Phrases: migratory interfaces, hybrid user interfaces, cross-reality interaction, transitional interfaces

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1 INTRODUCTION

The emergence of Virtual and Augmented Reality (VR/AR) devices opens up the design space for interaction within immersive environments. One promising interaction possibility is the use of hybrid user interfaces [7], which combine cross-reality (XR) devices such as AR head-mounted displays (HMDs) with other, heterogeneous device technologies to compensate for the disadvantages of one device with the advantages of the other. For example, the combination of touch devices with AR HMDs (e. g., [12, 17]) can provide a familiar interface and haptic feedback, allowing for more precise interaction than mid-air gestures. Such hybrid user interfaces typically involve the synchronous use of heterogeneous device technologies – but what about asynchronous use?

Consider Apple's Handoff[1] feature: users start writing an email on one device (e. g., desktop, laptop) and can finish writing that email on another device (e. g., smartphone). Handoff transfers the application state (i. e., the content of the mail to be written) from one device to another. This works well for homogeneous devices supporting similar modalities such as (physical or virtual) keyboard input and 2D screen output (e. g., desktop, laptop, smartphone): the content of the mail is stored in the cloud and shown in different, yet homogeneous views (on the desktop, laptop, or on the smartphone). While we can employ a fluidly responsive design to support screens of different sizes for providing access to the same content, sharing this content across realities on the Virtuality Continuum [14] (e. g., from a smartphone to an AR environment) may be more complex. Here, we have to consider additional aspects, such as representing the same content in both 2D (i. e., smartphone screen) and 3D (i. e., situated hologram), or switching between entirely different input modalities (e. g., from a virtual keyboard on the smartphone to gestures or voice commands). To ensure that the user can effectively make this switch between devices, transitional interfaces must be designed such that the mental connection between reality is maintained.

We therefore propose the idea of *asynchronous hybrid user interfaces*, where heterogeneous (i. e., non-immersive and immersive) devices are used *sequentially* (see Figure 1). While the sequential use does not necessarily offset the individual device-specific disadvantages with the advantages of another interface, it allows users to choose the appropriate device for a given sub-task. In this position paper, we will further explore the use of asynchronous hybrid user interfaces by discussing the current *background*, providing an *example scenario*, and presenting initial *transition challenges*.

2 BACKGROUND

Feiner and Shamash [7] define *hybrid user interfaces* as merging the "visual and interaction spaces [of] heterogeneous display and device technologies [to] take advantage of the strong points of each [device]". Recent work has demonstrated a variety of hybrid user interfaces, combining devices such as tablets (e. g., [12]), smartphones (e. g., [17]), or large interactive surfaces (e. g., [6]) both with AR as well as VR (e. g., [16]) environments.

Though Feiner and Shamash only consider the simultaneous use of devices to *merge* their "visual and interaction spaces", we also consider the use of *asynchronous* hybrid user interfaces, where devices are used in sequence to take advantage of their individual strong points. While such asynchronous use could also be considered a *migratory interface* [5], we argue that – depending on the fluidity of the transition – such interfaces more closely resemble hybrid user interfaces, especially as they combine heterogeneous device technologies. For example, Berns et al. [2] combine a desktop code editor with a synchronized 3D view of the resulting model, allowing users to view the created model either on the desktop or directly in VR. Similarly, the Unreal Engine SDK[2] extended their desktop editor with a dedicated VR interface, allowing users to choose the suitable environment for a given task when creating 3D scenes.

[1] https://support.apple.com/en-us/HT209455
[2] https://www.unrealengine.com

Although there seems to be a trend towards allowing users to migrate from one reality to another, there has been little research in terms of the actual transition between the necessary devices. Yet, there is significant overhead when switching between displays [9, 15] and therefore a high transaction cost [10]. As this may become worse when users have to not only switch between homogeneous devices (i. e., displays), but also between entirely different device classes (e. g., desktop and VR HMD), we regard *transitional interfaces* [3, 8] as an important aspect of asynchronous hybrid user interfaces. In this context, the concept of *activity-based computing* [1] can be helpful for transitioning across devices. For example, ActivitySpace [11] shows how content can be easily transferred across homogeneous devices in an activity-centric workflow.

3 EXAMPLE SCENARIO

We use a data analysis workflow as an example scenario to illustrate a possible use case for asynchronous hybrid user interfaces, which also highlights the role of transitional interfaces. Here, a data analyst might be interested in different representations of the same data set. To exploit the advantages of different environments, a future data analysis application might combine a traditional desktop interface with an immersive environment using a head-mounted mixed reality device: While the traditional desktop user interface could be suited for the analysis of aggregated data in 2D, the immersive environment might lead to additional insights based on the opportunity to walk in the data (e. g., investigating a 3D crime scene) or display data in-situ (e. g., situated visualizations [4]). For such workflows, recent work (e. g., [12, 17]) has shown the benefits of using such hybrid user interfaces. However, using both devices at the same time may become cumbersome, since not all workflows (e. g., working solely on the desktop) can benefit from the advantages of a hybrid user interface.

Instead, we envision the use of a *handoff* feature that allows users to seamlessly switch devices and continue with their work. For example, users could start their analysis with an overview of aggregated 2D visualizations on the desktop (see Figure 1 left), then switch to an immersive environment to make use of the stereoscopic view or investigate the data within its environmental context (see Figure 1 right). Similarly, users may want to walk through a data visualization to gain a deeper understanding of it, and then return to the desktop to consolidate and statistically validate their findings. In both cases, the application needs to support the user's transition, not only between different heterogeneous devices, but also between different realities on the Virtuality Continuum (e. g., from virtual reality to real-life and back).

4 TRANSITION CHALLENGES

Based on our example scenario, we identified the following challenges in transitioning between devices:

- **Loss of context:** How can we maintain the user's context and spatial memory when switching between devices (e. g., when an outlier was detected in the data)? Here, a seamless transition between realities can be helpful (cf. [12]), but is hard to establish with heterogeneous devices and differing data representations. We aim to explore techniques for achieving this, for example by allowing the user to create annotations or place visual markers to highlight particular data points, which then persist across realities.
- **Linking content:** How can we establish a mental connection between semantically identical content (e. g., visualization) yet visually different representations of the content (e. g., 2D visualization on the desktop and 3D visualization in an immersive environment)? The field of visual analytics uses techniques such as linking and brushing, or multiple coordinated views that provide different views on the same data – we therefore want to investigate whether these techniques can be transferred to our use case.

- **Transitioning between hardware:** Although XR devices are becoming increasingly ergonomic, the act of switching between, for example, a desktop screen and a VR HMD is still cumbersome. Here, we want to explore techniques that aid in this transition. In addition, we want to investigate the tradeoff between less immersive yet more convenient (e. g., handheld AR) and more immersive but less convenient (e. g., VR HMD) XR devices which could facilitate the transition between environments.
- **Consistency tradeoff:** How can we provide a consistent user experience across realities without reducing the strong points of each reality? For example, while the desktop profits from the familiarity and precision of a WIMP environment, a VR environment is more suited for 3D user interfaces [13]. However, this can lead to inconsistent interaction, which may result in an increased mental demand for the user. In contrast, reconstructing the desktop interface in VR (e. g., using 2D panels and pointing with VR controllers) may increase consistency, but may also lead to an inferior user experience. We aim to explore the impact of consistency and ways to maximize it, for example by recreating the 2D desktop UI in VR initially and then gradually morphing this to a 3D UI, or enabling the user to trigger this transformation themselves.

5 CONCLUSION

In this work, we describe the use of asynchronous hybrid user interfaces as a future direction for transitional interfaces and provide a list of future work opportunities based on an example scenario. Instead of using heterogeneous devices (e. g., tablet and AR head-mounted display) simultaneously, we aim to explore the potential in using these devices *asynchronously* – thereby extending the definition of hybrid user interfaces. Here, an essential challenge lies within the transition between these two environments. With this, we hope to incorporate novel XR devices into traditional (e. g., desktop-based) workflows to combine the advantages of different realities across the Virtuality Continuum.

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