Cross-Reality Hypermedia: Towards Flexible Collaboration Across Heterogeneous Information Spaces

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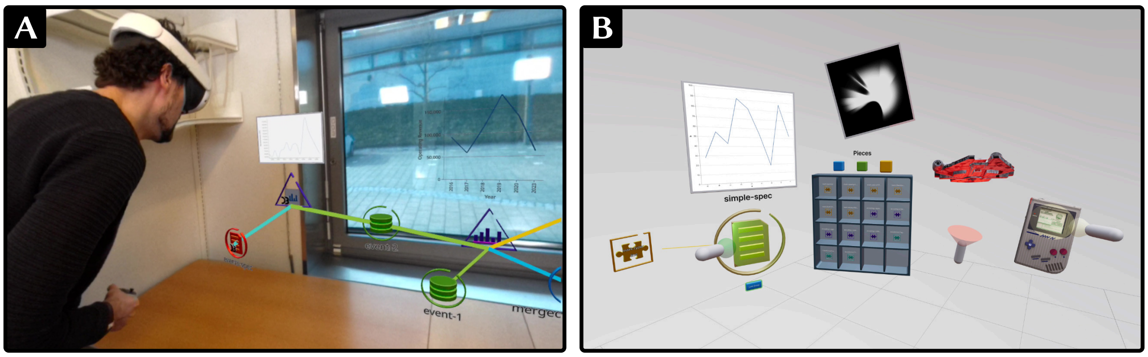

Fig. 1. **DashSpace and Spatialstrates**: (A) The DashSpace system for collaborative immersive analytics on the Web. (B) The Spatialstrates platform for extensible, collaborative XR applications on the Web with custom flashlight and 3D model elements in addition to DashSpace visualizations.

Mixed reality (MR) software is typically designed as single-purpose applications for specific use cases, such as whiteboarding or sticky notes, and remain largely isolated from traditional computing platforms like desktop computers. While most computer work still occurs on these, moving between traditional devices and MR is often difficult or impossible. We propose *Cross-Reality Hypermedia*, where traditional and MR applications live within the same medium. Cross-reality hypermedia utilizes principles and mechanisms from the Web and is characterized by three qualities: It provides *congruent information spaces* across 3D and 2D spaces, it enables *ad-hoc sharing and live collaboration*, and enables *transclusion of space and elements* to compose MR and desktop compatible applications. We illustrate these qualities through an envisioned use case of two scientists, collaborating together across 3D and 2D spaces. We discuss the technical challenges as well as other open questions like supporting legacy applications.

Additional Key Words and Phrases: Extended Reality, Cross-Reality, Collaboration, 2D/3D Spaces, Hypermedia

1 INTRODUCTION

Collaborative mixed reality (MR) software is most often designed as applications to support a particular task such as collaborative whiteboarding [6], note taking on sticky notes [12], remote instruction [10], or education [2, 14]. However, most computer work happens on traditional 2D interfaces on laptops, tablets, or phones, and transitions from 2D to 3D in MR is a challenge. Consequently, current MR experiences remain largely isolated from conventional computing [7]. Mayer et al. [9] argue that there is a lack of standardization for designing transitions in MR, and transitions are disruptive and interrupt workflows. Consider the case of collaborating remotely on a digital whiteboard. Using an MR application might support synchronous collaboration around a whiteboard, when multiple people work together. In the current

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software landscape, one would need to make a choice between a desktop digital whiteboarding application like Miro[1] or a MR application like Blended Whiteboard [6]. This is what we call *heterogeneous information spaces*, e.g., having a 2D information space on the laptop and a 3D space in MR. Transitioning between these information spaces is currently impossible—and an under-explored area of research.

Extensive bodies of prior work have explored two of the challenges posed by this workshop [5], concerning (1) how to support collaboration across heterogeneous physical spaces [13], and (2) how to support heterogeneous device configurations [1]. However, there has been no attempt to conceptually integrate these heterogeneity challenges into a single system concept.

To address this gap, we are looking at the relationship between these two types of heterogeneity and how they affect each other, and propose the concept of *Cross-Reality Hypermedia*. There is a need for a cross-reality [1] *platform*, rather than many single-purpose MR applications, to enable compatibility with 2D desktop interfaces. In the remainder of this position paper, we describe our vision of cross-reality hypermedia, propose three key qualities of it, demonstrate an envisioned use case of such a platform, and discuss open questions and challenges for this concept.

2 CROSS-REALITY HYPERMEDIA

Instead of isolated MR application, as we see them today, we imagine the future of mixed reality as a collaborative *Cross-Reality Hypermedia* platform where navigation between 2D and 3D spaces is as easy as following links, heterogeneous content can exist and be interacted within the same space, and the same content can be seen and edited on 2D or 3D devices simultaneously in responsive ways. We use a hypermedia system every day when using the Web, and WebXR has given us the possibility to create MR applications on the Web. However, we want to push further and apply the strengths of the Web also to MR applications.

Previously, we have created a collaborative, web-based, open[2] system, DashSpace [3], which enables collaboration in augmented and virtual reality (AR/VR) in the domain of immersive analytics. Subsequently, we distilled the core features of the system into a modular, package-based platform called Spatialstrates.[3] Spatialstrates enables to create collaborative, extensible, and reprogrammable MR applications on the Web. We are now working on extending Spatialstrates towards our cross-reality hypermedia vision, by natively supporting 3D as well as 2D spaces, allowing transclusion of spaces and elements into each other, and extending its collaboration features. These changes aim to elevate Spatialstrates towards supporting the following three qualities:

Q1 — Congruent Information Spaces. When working across information spaces, e.g., a 3D space in MR and 2D space on desktop, cross-reality hypermedia must create a bridge and provide a congruent information space. Elements need to be represented accordingly across these different dimensions—similar to how responsive design adapts to various screen sizes and input modalities. A possible "bridging space," might be a 2D canvas, akin to Miro: it provides a continuous space, similar to 3D space in MR, but is well suited for 2D display and mouse and keyboard input—contrary to showing a 3D scene on desktop.

Q2 — Ad-hoc Sharing and Collaboration. A strength of the Web is that content on it is accessible across all devices and platforms with a web browser—including desktop computers, mobile devices, or standalone head-mounted displays (HMDs) like the Meta Quest 3 or Apple Vision Pro. Sharing documents in web apps is often as easy as sending a link to

[1] Miro: https://miro.com
[2] DashSpace on GitHub: https://github.com/Webstrates/DashSpace
[3] Spatialstrates on GitHub: https://github.com/Webstrates/Spatialstrates

an URL to someone. This flexibility is lacking in conventional MR apps that typically require installing the application on the device first. Further, live collaboration is becoming the default in web apps for productivity.

Q3 — Transclusion of Space and Elements. Transclusion is a key feature of the modern Web: embedding the same content in multiple locations. While often merely used for transcluding content display-only, the Webstrates [8] platform shows how transclusion can facilitate embedding interactive, persisted documents and even add new functionality through transclusion. MR applications lack this level of composability of being able to embed, for instance, a part of one application into another. Transclusion in cross-reality can allow for constructing meaningful shared spaces, supporting both loosely and tightly coupled collaborative work [11]—integrating otherwise heterogeneous information spaces both in terms of physical spatial layout and different devices.

3 ENVISIONED USE CASE

Tom is a molecular scientist working on the design of protein molecules. For his research, he has to design a variety of protein structures and compare them. For his new project, he starts by creating a new space in Spatialstrates.

2D Canvas with Laptops. At his laptop, the space is represented as a 2D canvas, similar to the likes of Miro. He can add molecules to the canvas, which are represented as small thumbnails of the structures. While the thumbnails give him a rough idea of the structure of the molecules, seeing them in 3D would allow a more detailed comparison.

3D Immersive View with HMDs. With Spatialstrates, he can simply take on his HMD and open the space in his office in AR (Q1). All molecules are initially placed on a 2D plane—exactly how he arranged them in the 2D canvas—but are represented as 3D models of molecules (Q1). While comparing them, he can move them around in his office, clustering similar designs based on landmarks in the room. For instance, he arranges more stable structures on his desk, while placing more unstable structures around the coffee table.

Sharing and Loose Collaboration. For his current project, he collaborates with Samantha, a colleague from a lab in another university. He creates a shared container—represented as an outlined 3D box—and moves the box around a set of structures. The container transcludes a third, shred space into his personal space (Q3), and by moving it around the elements, it moves the elements into this transcluded space. To let Samantha know what he needs from her, he adds a floating note into the container, describing his question regarding the structures. He then sends Samantha a link to the container (Q2), which creates a copy of that container in her own space, including the elements within it. She can place the container independently from Tom in her office, as only the size of and space within containers is shared. She can now work on the same structures as Tom in an asynchronous fashion.

Tight Collaboration. The next day, while working on the structures in MR, Samantha has a suggestion for Tom. She moves up to the container and changes its collaboration level from *loose* to *tight* collaboration (Q2). On the tight collaboration level, Samantha's 3D avatar and voice communication is shared with Tom once she is getting into proximity of the shared container. She calls out for Tom, who notices Samantha's voice coming from the shared container. Upon moving up to it, his avatar also shows up in Samantha's view around the shared container. During their discussion, Samantha drags another structure from her own space into the shared container, which becomes visible to Tom (Q3).

Collaboration Across Dimensions. Halfway through their discussion, while they are discussing an important part of the new structure, Tom's HMD runs out of battery. With Spatialstrates, he can move back to his desktop computer (Q1), and navigate the 2D canvas—a projection of the 3D space—to the shared container and continue talking with Samantha about the structures. Now, back at his computer, he decides to try out Samantha's suggestion by creating a new structure and adding it to the shared container from his 2D canvas view. Samantha sees the new structure appear in 3D space in her view. This allows them to continue their discussion and decide on a structure to move forward with.

4 DISCUSSION

We are currently working on integrating the above features—such as spaces, containers, and extended collaborative support—into our Spatialstrates platform. However, there are still a series of open questions. A technical challenge of moving between 2D and 3D is the need for spatial relationship-preserving transformations: By projecting to lower dimensions, there is an unavoidable loss of information. Different transformation provide different trade-offs, for instance, by preserving either distances or angles and directions. However, it is still unclear which are best suited or if the transformations used should depend on the current scenario.

A more fundamental question is how to interoperate with legacy applications. The Web offers a plethora of tools and applications, however, it is not clear how such tools could work together with cross-reality hypermedia. While this challenge does also exist for regular desktop software, cross-reality hypermedia might face the additional challenge of MR software created with game engines like Unity or Unreal, which cannot easily be made compatible with the Web.

Lastly, the WebXR API is not yet finalized and still under development. Live collaboration is also not an inherent part of the web stack, but rather added individually on top by each web app—with platforms like Webstrates [8] exploring how such an integrated method could look like. Hence, one might say, it would be wise to wait for future, more mature APIs and standards. Still, the Web and WebXR offer many properties that we look for in cross-reality hypermedia and are a reasonably stable platform to built upon for now. While building on such a platform does prevent fulfilling the principled vision fully, it might still offer a pragmatic solution for exploring cross-reality hypermedia. Some tensions between a principled vision and its pragmatic implementation are inevitable in research—something we experienced ourselves in the past [4].

5 CONCLUDING REMARKS

We have proposed *Cross-Reality Hypermedia* as a inherently collaborative platform for MR applications, which activates mechanisms like transclusion or ad-hoc sharing from hypermedia. Following this approach, MR applications might be able to move from single-purpose applications towards more a flexible platform. Further, by transcending the 3D space and also supporting 2D spaces on traditional computing devices such as laptops, it might enable more fluid transitions between the two, reducing the friction currently prevalent when working across MR and desktop. We are looking forward to discuss these ideas with the other participants during the workshop.

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