

Shared Engagement in Digital Environments with Extended Reality and Tangible Interaction

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Abstract

Emergent interactive technologies – such as extended reality (XR) and its related subcategories augmented, virtual and mixed reality– are increasingly used in interdisciplinary research endeavors. These technologies aim to explore how smart glasses and headsets that overlay digital objects may support the design of collaborative experiences that enhance human interactions in the physical world. In this short paper, we briefly outline the possibilities of immersive technologies for research and how the Extrality Lab at Stockholm University serves as an infrastructure to prototype state-of-the-art solutions that merge physical tangible interaction and virtual environments in novel applications. We also describe how 3D digital tools may be used for research purposes, taking as an example the project SECE, which aims to study novel interactions, technology-supported artistic expressions, and the future of mobile computing in a cross-disciplinary team in Stockholm. More details about the Extrality Lab at <https://extralitylab.dsv.su.se/>.

Keywords

Virtual Reality, VR, Mixed Reality, MR, Extended Reality, XR, Human Computer Interaction, Interaction Design, Art, Performance, Collaboration, Telecommunication, 6G,

1. Introduction

The interplay between technologists and humanities scientists has enabled the advancement of scholarship in digital humanities, the interdisciplinary field concerned with the application of computational or digital methods to questions in humanities research, along with the critical examination of how digitalization shapes culture and society [1, 2]. Libraries and museums, which may be stereotypically attributed as analog settings, have been early adopters in the technological disruption. Even the first optical character recognition (OCR) algorithms were rapidly used for digitizing historical books at scales not possible with manual methods [3]. Similarly, more recent advances in 3D scanning and computer vision are the foundation for virtual tours of cultural heritage sites and creating digital replicas of archaeological artifacts and relics that require delicate physical preservation [4, 5]. In this paper, we discuss the possibilities of immersive digital media and tangible interaction as research methods in cross-disciplinary work. More specifically, we refer to the emergent technologies named Extended Reality (XR) and the potential of using the Extrality Lab at Stockholm University as a piece of infrastructure to support new research endeavors in digital humanities [6].

The acronym XR is an umbrella term for several tools that combine digital 3D objects with physical 3D space. It encompasses other technologies known as virtual, augmented, and mixed reality (VR/AR/MR, respectively). VR fully immerses users in computer-generated environments, while AR overlays digital information onto the real world, and MR allows digital and physical elements to interact in real time [7]. Researchers have largely studied the opportunities and challenges of XR experiences that are possible

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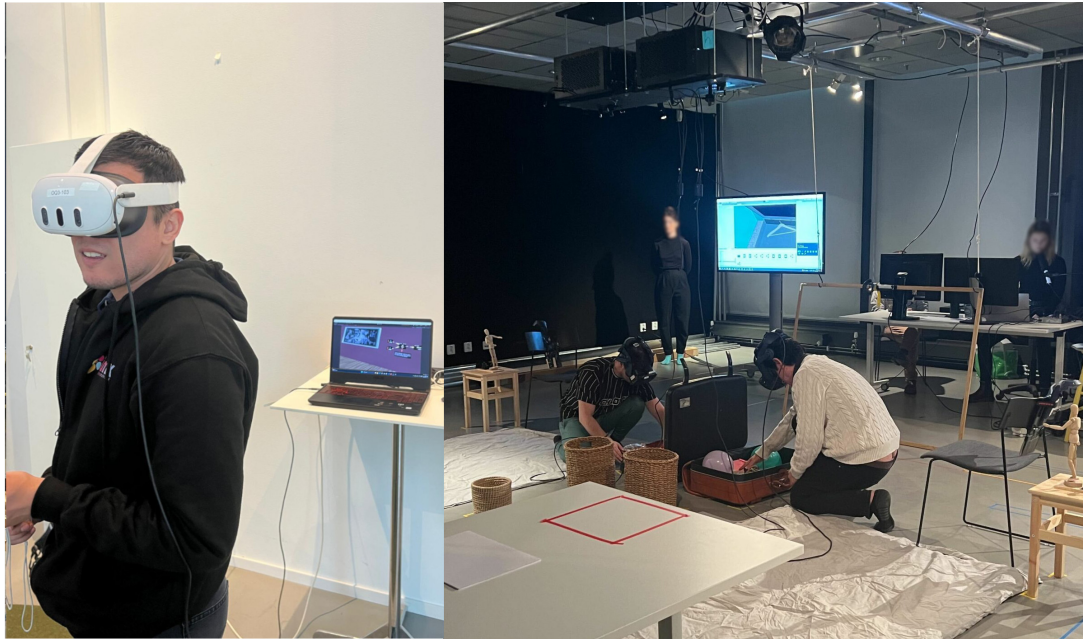


Figure 1: Resources at Extrality Lab: The multifunctional setup at Extrality Lab allows easy transition from standard seated settings to open spaces for public demonstrations. *Left:* A person wearing a headset to explore a single-user XR experience. *Right:* Two participants engage in a shared narrative that combines virtual worlds and physical objects with tangible interaction.

beyond purely physical or digital spaces. More recently, policy makers have also outlined initiatives to explore XR, such as the European roadmap for education and healthcare [8] or the Swedish funding in XR for sustainable innovation¹.

An underlying principle of these immersive systems is to create *hands-free* digital applications that let users collaborate without diverting attention to physical screens, including phones. The main interface in XR utilizes smartglasses and headsets as a medium to interact with 3D content through natural gestures (e.g., voice, hands, eye movements) [9, 10]. For instance, a museum visitor wanting to know more about a piece of art would get digital information projected directly onto their glasses, rather than reading a label or a screen [11]. Similarly, a collaborative project with XR would let people maintain interactions while standing and facing each other, where the relevant information appears seamlessly as virtual panels in the physical room rather than having to sit in front of physical screens [12, 13].

Overall, XR may support digital humanities by creating immersive, interactive environments that allow scholars and the public to experience cultural, historical, and artistic artifacts in new ways. For researchers, it enables novel forms of data visualization, exploration of sensitive objects, or interactions blending storytelling with embodied experiences that are aware of the physical space. In the remainder of the paper, we describe Extrality Lab as a physical space that may be used as an infrastructure for the exploration of XR for varied use cases, and also summarize the project SECE as a successful example that leverages the infrastructure to explore questions related to interaction design, future 6G networks, and technology-supported artistic performances in other words blending research from computer science, engineering, and the arts.

2. Extrality Lab: Extended and Tangible Reality Lab

The Extrality Lab is a central research environment dedicated to advancing knowledge in immersive systems, tangible interaction, and embodied computing, as well as enabling novel digital humanities research approaches. It may be considered a suitable infrastructure for digital humanities [2]. Equipped

¹<https://www.vinnova.se/en/calls-for-proposals/emerging-technology-solutions/feasibility-studies-xr-sweden-6g-2024-01699/>

with a full suite of XR devices, professional media production tools, and a fabrication workshop for physical prototyping, the lab provides researchers with the means to conduct systematic experimentation on the design and evaluation of emerging interaction paradigms.

The physical and human resources available at Extrality Lab have served as a scientific and technical framework for existing research projects at higher education institutions and through collaborative partnerships. Some of the developed immersive experiences have targeted the design and evaluation of educational tools to explain abstract concepts, such as learning introductory-level programming structures [14] or encryption algorithms for cybersecurity [15]. Another line of research in interaction design and user modeling has explored how novel 3D interfaces may affect human factors like the sense of embodiment toward digital avatars [16] or the elicited emotions from virtual content [17].

Lastly, the intersection of XR and related immersive technologies with artistic performances has facilitated the understanding of how performers and audience members interact in worlds with virtual and tangible interaction (see Figure 1). These activities explore novel opportunities of participation, their collaborative roles, and their agency within artistic productions [18]. The infrastructure at the Extrality Lab has been available to keep exploring similar questions through the lens of emergent technologies, such as in the SECE project described below, which represents the future of mobile computing and shared engagement in immersive digital environments.

3. SECE: Shared Engagement in Cultural Events with Mixed Reality

3.1. Motivation

MR in the context of multi-user experiences is relatively unexplored due to technological restrictions that were overcome only in 2024, allowing headsets to run colocated applications in a wireless mode without depending on desktop computers for 3D rendering. Therefore, SECE is one of the first projects to build MR collaborative experiences for shared engagement in digital environments and test them in a real-life outdoor setting. The project is a collaboration between the Extrality Lab at Stockholm University, the ConsumerLab at Ericsson Research, and Kulturhuset Stadsteatern. This project explores multidisciplinary research questions related to XR interactions, telecommunications (5/6G, WiFi 6e and beyond), and artistic performances, such as: *how can immersive MR interactions enable new dynamics between actors and audience in an interactive performance?*, *what are the network challenges when running a mobile MR experience outdoors?*, and *how can MR support novel and meaningful social interactions when designing interactive artistic performances?*

Previous XR research has primarily addressed either single-user experiences or collaborative systems relying on multi-device configurations. Current headsets feature real-time see-through capabilities with co-location features through the real-time matching of a room's point cloud, allowing several users placed in the same space to interact with the same aligned virtual content.

As for use of VR in both learning and the arts, as presented at HumInfra Conference 2024 [19], new technology brings opportunities but also challenges on how to organize the process of synchronizing the work of all parties involved. XR comes with its own challenges that need addressing when designing and implementing. For SECE, the core is the novel multi-user colocated application that allows transitions between reality, MR, and VR using digital portals to support the study of how smartglasses and headsets may work as a platform to perform synchronous and collaborative tasks that seamlessly transition between fully digital and fully real settings (see Figure 2, and next section). A full description of the technical setup has been published previously in a scientific conference [20, 21], and more related information about SECE is available at the project's website².

²<https://www.su.se/english/research/research-projects/mixed-reality-shared-engagement-in-cultural-events-sece>

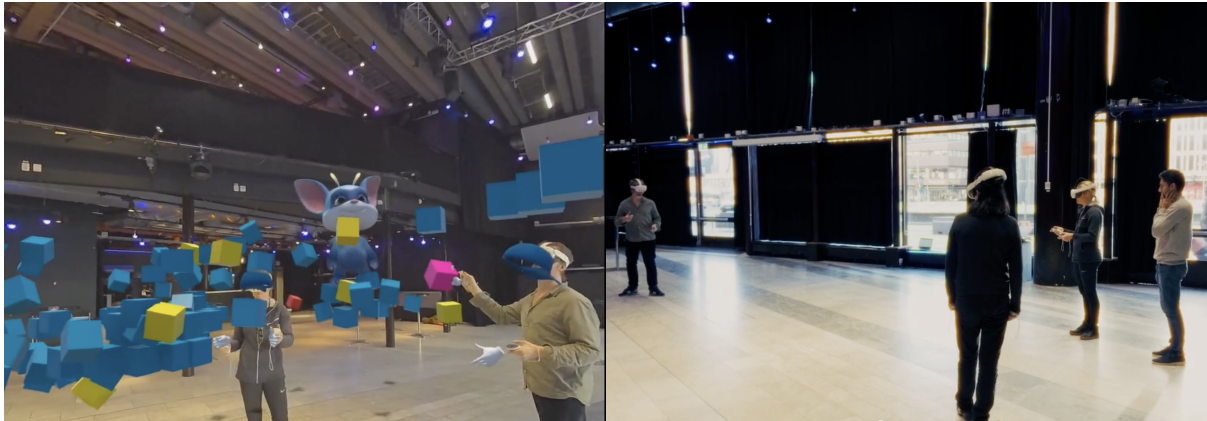


Figure 2: Snapshot of the XR collocated experience SECE: *Left:* Several participants wearing XR headsets interact with co-located virtual cubes (blue) to design an art performance combining real and virtual objects. *Right:* Perspective of a participant not wearing XR headset and therefore unable to see the digital content in the physical space.

3.2. Demo and Implementation

XR Interaction Applications: Previous work on multi-user XR systems for cultural heritage found that object interactivity and user-generated content significantly enhance engagement [22]. Therefore, in the SECE project, we developed applications to facilitate the design of artistic participatory experiences. First, the leader of the artistic performance can perform *object placement* (see Figure 2-Left), where a set of virtual 3D elements will float in the physical space and become interactable for anyone wearing a headset. A second application enables *mid-air drawing*, where the virtual pens can be placed in the 3D space and the participants can create scribbles and traces in the 3D space. The third application supports *character control*, where the movement trajectory of a character, a butterfly in the SECE case, is controlled by the users to move the virtual elements in the physical room. Lastly, spatial audio sources can be placed to complement a multisensory experience. All virtual elements are updated in real-time to give all participants a synchronous immersive experience.

Performance Preparation: The first participant entering the XR experience acts as the session’s leader and should set up a digital scan of the physical room to be processed in the headset. This process captures point-cloud data from the physical space and the contextual information of the surrounding physical objects, such as tables, doors, or plants. The room’s contextual data creates the spatial anchor, enabling the collocation of other participants. When the other participants access the same application in their headsets, the room data is synchronized to let everyone see the virtual objects in the same place, despite looking at them from different perspectives.

Artistic Storyline: The leader of the artistic performance can use the available XR interaction applications to control the narrative of the immersive experience. The preliminary performative storyline of SECE unfolds in three acts.

Evaluation: The objectives of the SECE project involve analysing how XR reshapes sensemaking, artistic expression, and audience engagement in collaborative performances. The first analysis moment was conducted indoors at Kulturhuset in June 2025, and the final outdoor performance is planned for June 2026 at Sergelstorg. The data collected is primarily qualitative, with interviews and video recordings that inform the possibilities for the future design of mobile digital experiences with immersive systems, specifically in artistic settings.

4. Conclusion

This paper describes Extended Reality (XR) as a tool or method that may support current research in digital humanities. More specifically, we describe how the Extrality Lab can serve as an infrastructure for the design and development of such projects at the Department of Computer and Systems Sciences (DSV) of Stockholm University. Lastly, we present the SECE project as a case of multidisciplinary work that creates a complex MR interactive experience to address questions related to interaction design, telecommunications, and performative arts.

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