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Out There, Anywhere: Digital Proxies for Threatened Cultural Heritage Sites and Structures

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Abstract

Cultural heritage sites and structures located in remote environments or composed of fragile materials face numerous threats from degradation, inaccessibility, and lack of preservation support. This paper introduces an in-progress multimodal digitization project for a remote sculpture trail, an open-air art installation composed of wooden sculptures, in southwest Virginia. This project combines photogrammetry, Gaussian splatting, LiDAR, volumetric capture, and oral history to create an immersive digital proxy of the site and experience. It proposes a replicable, scalable model for capturing and preserving complex cultural heritage assets, leveraging interdisciplinary expertise and prioritizing cross-departmental collaboration and digital preservation strategies for XR content. This paper presents the comprehensive project plan, details current progress, and discusses ongoing planning considerations.

CCS Concepts

• ***Information systems*** → ***Digital libraries and archives;*** • ***Computing methodologies*** → *3D imaging; Virtual reality;* • ***Applied computing*** → ***Arts and humanities;*** • ***Human-centered computing*** → *Interaction design process and methods;*

1. Introduction

While cultural heritage materials have often been hidden from the public eye or degraded over time for various reasons, structures, and environments related to or containing unique materials also face a unique subset of threats due to their size, scale, location, and exposure to the elements. Damage from climate change impacts [Bro24], deterioration of materials from neglect or lack of resources [MBB22], and remote locations or "lack of accessibility" [LF23] create numerous barriers to the experience and lifespan of these spaces and objects. Where conservation and physical accessibility efforts may face limitations, 3D technologies can serve as a proxy to digitally capture, preserve, and make accessible immersive experiences of remote, degradable, or fragile artifacts and structures.

This paper will introduce an ongoing case study that combines 2D, 3D, Gaussian splatting, Light Detection and Ranging (LiDAR), volumetric capture, spatial audio recording, and oral history to mimic the experience of visiting a remote sculpture trail in southwest Virginia created by a regional artist. The process will prioritize integrating multiple technologies, the artist's requirements, and intentional considerations for digital preservation and sustainable practices.

2. *Out There* Project Description

Charlie Brouwer is an American artist known for his wooden sculptures and mixed media drawings and paintings that explore themes of place, community, and nature. Since becoming a full-time artist in 2008, he has exhibited over 300 times internationally. In 2022, Mr. Brouwer was diagnosed with a vision impairment that has left him legally blind, with his remaining sight continuing to deteriorate. His most impactful work–wooden sculptures–are vulnerable to decay and require ongoing manual restoration. One of the most significant permanent exhibits is *Out There*, a collection of 38 sculptures situated along a trail on his remote, wooded property in southwest Virginia. Facing risks posed by his declining mobility, the exhibit's remoteness, and the degradation of the wood, Virginia Tech University Libraries (VTUL) is partnering with Mr. Brouwer to launch an extensive digitization effort of the *Out There* sculpture trail [Bro10].

This project unfolds in three primary phases, shown in Figure 1: 3D sculpture capture and 2D artwork digitization, capture of the environment immediately surrounding each sculpture, and oral history methods to record Mr. Brouwer telling each sculpture's story. These elements will form an immersive virtual experience supported by VTUL's digital library infrastructure and collaboration between the 3D Lab and Applied Research in Immersive Experiences and Simulations (ARIES). The presentation will feature a proof-of-concept of at least five digitized sculptures and ten drawing exhibits.

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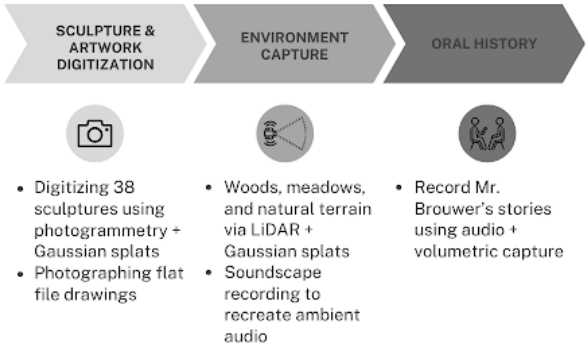

Figure 1: *Data collection workflows*

3. Literature Review

Drawing on concepts from earlier projects such as [BBDS*10] which aimed to construct a "virtual museum system starting from a set of archaeological pieces," and building on more recent work focused on cultural heritage and art, a 2018 survey [BPF*18] provides a foundational and comprehensive overview for identifying specific application areas for augmented reality (AR), virtual reality (VR), and mixed reality in cultural heritage contexts. The survey identifies five primary themes–education, exhibition, exploration, reconstruction, and virtual museums–and recommends technologies appropriate to the project's goals and anticipated outcomes. Falling primarily into the "reconstruction" category, *Out There* will align with these findings and is envisioned as a hybrid, multimodal experience.

Recent photogrammetry research on wooden and other cultural heritage objects has shifted from establishing basic methods to refining workflows for higher fidelity, interactivity, and interpretive depth. As integration with AR/VR expands, the field is moving toward more immersive engagement with digital artifacts, enhancing access while raising new questions about authenticity, presence, and sensory experience. A team in Venice capturing the Magazzini del Sale historical landmark switched from Faro scanners to photogrammetry to capture the full structure of the site to tell a more comprehensive story of the space and architecture [GBFG19]. Another photogrammetry project to capture wooden sculptures exhibited outdoors in Slovenia highlights the importance of not only capturing degradable cultural heritage objects for long-term access, but also for alternative interpretations that expand interactivity and experience [USV*22].

This work extends to higher education classrooms and pedagogical design, eliciting increased cognitive engagement [NBSR20], increased interdepartmental collaboration and community outreach [POM18], and enhanced practical learning methods in the classroom [AEJ*21]. This method also aids in avoiding the technological "learning curve" [POM18] references as a barrier to integrating 3D into the classroom by providing these integrations as a Library service oriented to education and scholarship at Virginia Tech and in the greater southwest Virginia region.

4. Methodology & Technical Interventions

Photogrammetry & Cross-polarization—The primary focus of this digitization effort is the preservation of the wooden sculptures. As organic material, the sculptures are inherently vulnerable to deterioration over time. The goal is to capture them in their current state to increase their ability to exist digitally long after physical degradation. We will use a combination of camera and drone imagery to create high-quality 3D models through photogrammetry [AGG22]. Some sculptures exceed 6 feet in height, requiring a drone to capture overhead perspectives accurately. The resulting high-resolution 3D models will support three outputs: 1) an archival-quality version for long-term digital preservation; 2) a lower-resolution derivative with high-quality texture maps to display on the Virginia Tech Digital Library using the babylon.js viewer; and 3) an optimized version for use in the immersive virtual experience. Figure 2. exhibits an example of a sculpture and its textured and untextured meshes.

Figure 2: *(left to right) Photo of an example sculpture and its textured and untextured meshes*

One of the implications of capturing objects in natural light is the inconsistency of lighting conditions and environmental shadows cast by the sunlight [Bar21]. Using powerful circular flash and cross-polarization methods [ABB*21] during image capture will help mitigate these issues by overriding the natural light and ensuring the highest quality and true surface color information [Bar20].

Environment Capture—Typical approaches to reality capture of real environments, via photogrammetry or LiDAR, generate large datasets that must be decimated and optimized for access via the Internet. The environment itself is not the focal point of the project's immersive experience and is challenging to capture due to being on a trail through a wooded area with a prevalence of small leaves, pine needles, and shrubs. To address those challenges and create a lightweight, web-performant background environment, the team will experiment with emerging AI-driven techniques such as Gaussian splatting [WYF*24] to capture the trail's environment. Gaussian splatting diverges from traditional mesh-based modeling and produces point clouds composed of "splats"—data-rich points that carry information on position, color, size, and orientation. This method offers improved rendering of reflective surfaces and more efficient capture of complex visual characteristics, such as the finely textured wooden surfaces of the sculptures, and will render efficiently on the web viewer.

Using a 360 camera, we will walk the areas immediately surrounding each sculpture on the trail, approximately a 10 foot radius, while recording video data. These videos will be converted into still images to serve as the main input data for the creation of Gaussian splats.

The backbone of the immersive virtual experience will be the visual data resulting from this capture method. We will build the Gaussian splats in the WebXR application and replace the sculpture data from the captures with the photogrammetry models.

Volumetric & Audio Capture—When visitors walk the sculpture trail, Mr. Brouwer often accompanies them, sharing the personal stories behind each piece. This storytelling component brings the sculptures to life and provides essential context. These stories are, at least publicly, undocumented and cannot be experienced without being on site. Recreating this experience in a virtual environment is a key priority. To achieve this, we will capture Mr. Brouwer giving the guided tour of the trail. One option is to record his voice and trigger the audio narration when the viewer approaches a sculpture. A more immersive option involves performing a volumetric capture [JHL*23] of Mr. Brouwer's narration, allowing his digital avatar to appear beside each sculpture in the virtual space. This will offer a strong sense of presence, that Mr. Brouwer is right there with the viewer, and provides a structure for the experience.

The final component will be a soundscape capture using a recorder capable of spatial audio recording to contribute to the immersiveness. This might include the sound of leaves rustling in the wind, the birds singing, and the insects buzzing. A soundscape recording will be produced for an area surrounding each sculpture.

5. Value & Impact

Interdisciplinary Overlap—This project is made possible through close collaboration across multiple departments at VTUL. The 3D lab will lead the capture of the sculptures, while ARIES will create the virtual experience. Together, these teams will capture the environment using Gaussian splatting, the soundscape, and the volumetric capture of Mr. Brouwer. The Digital Libraries & Preservation department will provide the digital library platform to host each component comprehensively, as well as the digital preservation framework and activities for long-term accessibility, guided by experts in ARIES. Incorporating 2D scans and oral history extends interdisciplinary collaboration further to include digitization experts, digital preservationists, and historians.

Immersive Experience Modeling—By combining strengths, we intend to develop a reusable model for designing and implementing holistic proxies of remote and endangered cultural heritage sites and structures. The proof of concept proposed in this paper is only a portion of the larger vision. As digitization of the entire *Out There* experience continues, it will enable people to experience it anywhere without physical accessibility concerns. This approach will enhance public access and educational use while also serving as a preservation strategy for at-risk environments, ultimately offering a scalable framework for future projects involving vulnerable or isolated cultural assets.

Digital Preservation Considerations—Despite international efforts to guide the digital preservation of complex objects like 3D models [AF24, FvHP*23, Art21], even less guidance is available for AR/VR, Gaussian splats, and volumetric capture. The multimodal nature of this project provides urgency to investigate sustainable practices, including comparing file formats and size, documentation for capture, processes, and future reconstruction, and robust metadata. These considerations include using open formats where possible, metadata that accounts for technical details, and continuing to develop preservation and access infrastructure to host and preserve XR content. Special attention will be paid to volumetric capture, another emerging technology with pipelines still in the exploratory phase to produce quality outputs. The already arduous capture process is still under development and is only possible through a single proprietary software called DepthKit, and results in complicated packages with mixed proprietary and non-proprietary file formats that will require further investigation.

6. Conclusion & Next Steps

The *Out There* proof-of-concept reported in this paper represents a significant integration of 3D capture technologies, emerging immersive experience design, and investigating long-term digital preservation practices for XR content. By combining photogrammetry, LiDAR, Gaussian splatting, volumetric capture, spatial audio, and traditional 2D digitization, this project demonstrates how multimodal technical and project management workflows can recontextualize and facilitate the digital preservation of complex cultural heritage structures and environments. As the project progresses from Phase 1 to Phase 2, the team will continue refining workflows to support scalable, sustainable digitization of the remaining sculptures and their environments. Interdisciplinary collaboration will remain central to project decisions as we navigate merging the technologies and exploring evolving formats and preservation strategies.

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