# Supporting Virtual Reality and 3D in Academic Libraries

## *Defining Preservation and Curation Challenges*


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**Abstract[1] – Academic libraries are increasingly adopting virtual reality (VR) technologies for a variety of research and teaching purposes, yet there is a lack of clear guidance in the community on how to manage these technologies in effective and sustainable ways. In June 2018, the University of Oklahoma hosted the second of three forums on the topic of using 3D and VR for visualization and analysis in academic libraries, as part of the IMLS-funded project, Developing Library Strategy for 3D and Virtual Reality Collection Development and Reuse (LIB3DVR). This project uses nominal group technique to collect data from the invited experts (from diverse academic disciplines and institutional contexts) at the Forum to identify common preservation and curation challenges in the visualization and analysis of 3D data and the management of VR programs. This paper describes the findings of this project and outlines strategies and techniques for curating and preserving 3D/VR.**



**Keywords – Virtual Reality, 3D Data, Libraries, Preservation, Curation**

**Conference Topics – Exploring New Horizons; Building Capacity, Capability and Community.**



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## I. Introduction

Virtual reality (VR) has resurfaced as an engaging and innovative technology, with a surge in the availability of low-cost hardware. Academic libraries are increasingly adopting VR as a means of providing enhanced access to collections of 3D models, new research tools, and new immersive learning environments for students [1]. VR is useful for enhancing visualization and analysis for big data applications [2, 3] and scientific research, and for contributing to increased engagement in the classroom [4, 5]. The demonstrated efficacy of VR for research and teaching purposes, and the increasing affordability of hardware, has inspired library administrators and technologists to introduce VR to makerspaces and other sites across university campuses, as well as to provide for the checkout of VR equipment by library patrons [6, 7].

The adoption of VR is part of a trend towards technological innovation now taking place in academic libraries; however, there is a clear lack of guidance in the library community on how to introduce, integrate, and sustain these technologies in ways that serve all library stakeholders. A multitude of institutions




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are tackling the same issues, oftentimes replicating similar work, indicating a need for leadership on the part of early-adopters, including academic libraries, to determine best practices for supporting VR technologies across different types of institutions. Practical considerations, such as designing systems to reduce motion sickness and increase accessibility, for example, have been tackled on an ad hoc basis, making it difficult to scale up VR services for widespread adoption. Similarly, preservation issues have not been adequately addressed for 3D/VR. The fundamental problem is that best practices have not been systematically collated, analyzed, and packaged for widespread dissemination and adoption across the community.

To address these challenges and aid in the maturation of 3D and VR as learning and research technologies, an interdisciplinary group of librarians and researchers from Virginia Tech, Indiana University, and the University of Oklahoma convened to develop a series of three national forums on this topic, funded by the Institute for Museum and Library Services (IMLS), as a project titled Developing Library Strategy for 3D and Virtual Reality Collection Development and Reuse (LIB3DVR) [8]. Each forum was designed to cover a particular phase of the lifecycle of 3D and VR within academic contexts: The first forum looked at 3D/VR creation and publishing; the second forum looked at 3D/VR visualization and analysis; and the third forum looked at 3D/VR repository practice and standards. This paper presents findings from the second forum, held in June 2018 at the University of Oklahoma, Norman, OK.

## II. Literature Review

3D and VR technologies offer new potential for interactive engagement with and analysis of spatially complex artifacts, spaces, and data, which enables the possibility of new insights [9]. They are also being used as immersive learning environments for a range of fields, from anthropology to biochemistry [10] to architecture and design [11]. Researchers in a range of fields are already incorporating 3D technologies into their scholarly practice in order to enhance their methods of analysis [12, 13, 14, 15]. Research has shown that scientists are able to make more inferences from 3D digital models than from photos, while humanists can visually represent texts, images, and material artifacts in VR spaces for detailed analysis and to better understand their cultural and historical context [16, 17, 18, 19]. In addition, the 3D representation of fragile or otherwise inaccessible artifacts opens up access to a host of archived objects for a wider audience of researchers, students, and the general public [20, 21].

Studies on the preservation and curation of 3D/VR have pointed out that as researchers increasingly use these technologies, there will be a greater need for archiving and preservation services [22, 23, 24, 25]. As emerging technologies, however, there is still a lack of knowledge about how best to create and curate the scholarly products of 3D/VR projects. 3D data is being valued for its potential to be reused beyond the original context of creation [26, 27], which makes it important to ensure adequate data curation procedures are in place. In recent years, a handful of domain-specific research groups have attempted to develop 3D data creation workflows and repository structures [28, 29], and metadata guidelines (e.g., the Archaeology Data Service's Guide to Best Practices [30]). Technical groups (e.g. the Khronos Group's COLLADA and OpenXR initiatives [31]) have been working towards interoperability standards for 3D/VR file formats, software, and hardware. Early 3D/VR metadata projects, such as Mourkoussis, et al. [32], have not seen their guidelines widely adopted. At the same time, more recent projects have identified a lack of suitable metadata standards, particularly with regards to preservation metadata [33, 34], as a serious challenge to working with 3D data. Bennet (2015) suggests, "3D data archiving remains a multifaceted web of decision points on file formats, their relational organization, packaging, and final storage" [35].

There have been some attempts to develop digital repositories and common metadata guidelines for 3D data [36], when it is framed as "cultural heritage" data. For example, the goal of the European-based, 3D-ICONS Project [37] was "to provide Europeana with 3D models of architectural and archaeological monuments." This project also developed metadata guidelines [38], which were released in 2013. It was announced in early 2019 that Europeana [39], the European Union's digital library platform for cultural heritage, would start introducing 3D materials into its collections [40] with guidance from 3D-ICONS.


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In 2017, the project team who established the IMLS-funded project, Community Standards for 3D Data Preservation (CS3DP) surveyed an international community of researchers and librarians involved in digital curation and 3D data acquisition and research (112 total participants). They reported that "72% said that they did not use best practices or standards for preservation, documentation, and dissemination of 3D data. Of those not using standards/best practices, 69% said that they did not use them because they were unaware of such standards" [41]. Cook and Lischer-Katz (2019) have defined three important preservation areas in which libraries can take the lead: Managing VR hardware and software obsolescence; establishing file formats for archiving 3D content; and developing metadata standards [42]. Moore and Skates Kettler (2018) also point to the importance of metadata: "Creating a standard for metadata and a set of best practice recommendations would have immense impact on the overall preservation and interoperability of 3D research" [43]. One of the critical challenges to common standards is the diversity of approaches being carried out as part of 3D and VR creation methodologies [44].

At the Coalition for Networked Information (CNI), Fall 2017 Plenary, Clifford Lynch noted that while in many cases it is now possible to support the full research lifecycle of a significant range of 3D objects at reasonable quality and cost, there remains a significant and important challenge to implement a whole library apparatus, including the development of good standards for storage and description; good provenance metadata to tell us where 3D objects came from; and suitable documentation specifying whether they are produced by scanning real objects in the world or are designed entirely on a computer (e.g., architectural CAD designs) [45].

A report published in February 2019 by the Council on Library and Information Resources argued that libraries need to take the lead in supporting "new and complex technical workflows, scholarly practices, and data curation and digital preservation requirements," if 3D/VR technology is to be widely used as a set of scholarly and pedagogical tools [46]. In many cases, academic libraries are already taking the lead in adopting these technologies, providing support and developing effective course integrations and research support. However, Cook and Lischer-Katz (2019) note, "the sustainability of VR as a legitimate library resource depends on managing VR-related data and digital tools throughout the research life cycle" [47]. Meyerson (2019) has suggested that establishing preservation guidelines for 3D and VR can follow existing guidelines for other types of software, with some modification [48].

The findings and analyses in these reports and articles unanimously point to a critical need to establish 3D/VR creation and curation best practices and standards, and they emphasize the essential role played by community engagement in establishing those best practices and standards. They also acknowledge that because of the diversity of approaches and contexts it is necessary to look closely at how a broad cross section of stakeholders is approaching this problem space in order to establish guidelines that will be useful for all involved.

## III. Research Objective

The main research objective of this phase of the LIB3DVR project is to determine how academic libraries and other institutions with 3D/VR programs are planning for the reuse and long-term sustainability of 3D and VR resources. Identifying the challenges and strategies in current practice will help establish a foundation for community-generated best practices and standards.

## IV. Methods

The project team assembled a two-and-a-half day forum in Norman, Oklahoma with fifteen expert participants, including academic librarians, researchers from a variety of disciplines, and commercial game designers and software engineers. Participants were selected by identifying national experts in representative fields, with an eye towards achieving institutional, disciplinary, racial, and gender diversity. The project team shared the participant list with an advisory board that provided further input on the selection of participants. In addition to the meeting of invited experts, a half-day public forum was held in which local stakeholders were invited to attend and discuss their experiences working with 3D/VR.

The project team used a nominal group technique to generate research data for this study [49]. Nominal group technique is a consensus-building method for achieving general agreement on a topic through face-to-face small group discussions. This method was adopted in order to reveal key challenges related to the visualization and analysis of 3D and VR data and the design and management of library programs to support those activities. The agenda for the forum was divided into special sessions on specific topics. Data were generated through methods of community note taking, facilitated using shared Google Drive documents for each forum session. At the end of each discussion session, a group note taker summarized and presented the views of each small group to the wider forum. Both the raw community notes and the summarized facilitator notes were collected and analyzed. Notes produced from the smaller groups and from the larger group form the basis of the findings. We validated these findings by disseminating an early draft of this paper to participants, asking them to correct, clarify, or elaborate on the paper's findings. The authors incorporated all participant feedback into a subsequent draft.

Data analysis consisted of grouping data from the community note taking documents into higher level categories based on the research objectives and emergent themes, following an inductive analysis approach [50]. A central part of the data analysis process involved moving from grouping specific examples of institutional practices and personal perspectives in order to link them to more general, community-wide phenomena. In this way, a set of shared challenges and strategies could be identified at the community level of analysis. One of the limitations of this methodology is that it is limited to a small group of experts, which could potentially leave out other perspectives. Including a public forum, which was open to more participants from a greater range of institutions, helped to mitigate this limitation.

## V. Findings

Participants were primarily concerned about the practical implementation of VR in their institutions, particularly the costs of maintaining VR equipment over time. Beyond the ongoing costs of maintaining and upgrading VR hardware and software, there are a number of other issues identified by forum participants that impact the management, use, and reuse of valuable VR content. These include the development of suitable documentation practices and tools for tracking the 3D content creation process; legal and ethical concerns, especially in the context of cultural heritage content; and preservation and curation concerns related to research transparency and reproducibility.

### A. *The Importance of Documentation*

Documentation was seen as essential by participants because it can impact the accuracy and reliability of the 3D models and the structure and behaviors of the VR environment. Ensuring transparency in the creation process of VR is essential so that future users can interpret the accuracy of the VR content, which impacts the types of inferences that they can make from it. Strategies suggested by participants for addressing documentation concerns included using project management tools that can document processes over time (i.e., producing process-based project documentation), documenting overall workflows, and using journaling and lab notebooks during the course of a project in order to keep track of decisions made in the production process. Another part of developing good documentation practices is getting into the habit of storing VR project files in open, well documented and widely supported formats, which would enable future users to be able to access the original source files that went into creating the VR project file. If original software is no longer supported, it becomes difficult or nearly impossible to open up VR projects and see how they were assembled, which makes it important to document which software packages were used for a given project.

### B. *Ethical and Legal Issues*

The need for documentation is also related to important legal and ethical questions raised by the use of VR content. Working with cultural heritage content in particular raises a number of concerns in this area. While historical materials are often in the public domain and not encumbered by copyright, there were concerns raised by participants about companies or organizations doing scanning projects and then claiming copyright on the resulting digital products. In addition, participants raised questions about how 3D scanning of a cultural heritage object might impact the integrity of the object, with consequences for the ownership and value of the original object [51]. This is particularly important when models are produced from culturally-sensitive materials. In other cases, in order to prevent "digital colonization," a term brought up by one participant, it is important for 3D and VR content creators to respect the cultural protocols of indigenous communities. In contexts where personal information may be captured via 3D or VR, data privacy was also seen as a potential issue.

In addition to these ethical and legal concerns, there are also intellectual property issues identified that could impact how VR content is used in the future. VR projects that employ plugins, interactions, models, or other components that involve third-party licenses are at risk of having limited options for reuse, or not being reusable at all if the underlying licenses or digital rights management (DRM) technologies place burdensome restrictions on users. One participant was concerned that DRM could restrict how 3D and VR content are reused, for instance, that DRM might one day limit which 3D-printed models could be printed (the participant was concerned that 3D printers might someday be designed to only print certain models that were authorized via restrictive DRM systems). Increasing use of "software as a service" models, which are built on "black box" systems and cloud storage, also complicates how legacy VR content can be sustained over time and how it can be used for research. This issue is an example of a legal issue that has implications for research transparency and reproducibility, which will be addressed in the next section.

### C. *Research Transparency & Reproducibility Concerns*

Being able to access research data and digital scholarly products over time has become an important aspect of research transparency and reproducibility. Participants voiced concern that if software relies on external servers and those servers are shut down some day, then access to the software may be lost. It may be nearly impossible to replicate research findings that relied on server-based software or proprietary software built with non-transparent processes and algorithms. Researchers in the forum were also concerned about how 3D and VR scholarly outputs could be cited as persistent scholarly objects if they rely on "software as a service"-based systems. One participant suggested that blockchain technology might be useful as a means of keeping track of provenance and the intellectual property chain. This is an area that deserves further investigation, as it may help to address some of the documentation and transparency challenges of managing 3D and VR over time, but with the caveat that other research has shown that blockchain may have limited utility as a preservation tool [52, 53].

Grant-funding agencies, such as the National Science Foundation, are making data management plans (DMPs) a required component of grant applications and preservation of research data is an important component of a DMP. Being able to preserve and access 3D/VR into the future is important for a range of stakeholders in the research community. The discussion around preserving 3D and VR content revolved around questions of 1) defining what elements of 3D/VR projects to save, 2) identifying the range of technological obsolescence and interoperability challenges that are typically encountered, and 3) defining strategies for preservation.

#### 1. *Defining the Objects of Preservation*

Participants tried to come to some consensus on what should be considered the most basic unit of a 3D or VR asset that might be reused in the future. Some answers included preserving 3D models along with the VR behaviors and "physics" of those models, including the structures and interactions between elements in the VR environment. In terms of preserving 3D models, one challenge is to identify how much quality is necessary. There was some discussion of preserving low-resolution models in a VR environment for re-use and some participants argued that preservation efforts should focus on the high-resolution models that are produced through 3D capture processes such as LiDAR and photogrammetry. One participant introduced the concept of the "smallest preservable unit" (i.e., the smallest unit that can be exported and used to reconstruct the VR environment or build new environments in the future), which could be defined depending on the particular use-case or the organization's preservation intent. One example of this is the concern over preserving the behaviors and interactions of objects in the virtual space. In terms of behaviors and physics, one participant pointed out that these elements could not be saved separately from the models or the VR environment because they are generated by the game engine that was used to create the VR environment, which can change as the game engine is updated over time. For instance, the Unity game engine, which is a commonly used platform for producing VR content, is constantly being updated and it is difficult to ensure that the behaviors of elements in a VR environment at one point in time will interact consistently in the future. Only the game engine design company has complete control over how those elements will change. Because of this, participants pointed out that this makes preserving the actual performance of a VR environment very difficult. While many of the elements may be preservable individually, this still does not capture how that VR environment behaves when in use. For that reason, forum participants emphasized the importance of documenting behaviors of VR environments using video recordings of users engaging with them.

*2. Obsolescence & Interoperability Challenges*

Participants pointed out that because of the complexity of VR technologies, the risk posed by obsolescence to the long-term accessibility of VR is very high. They pointed to the updating of firmware, dependencies on third-party software, and upgrading hardware as activities that could impact how the VR system behaves and whether or not older VR projects can be accessed in the future. Older VR projects may need to be migrated over time to new systems. For instance, one participant presented a case study on the preservation initiative to preserve the Virtual Harlem project (a project developed by Dr. Bryan Carter, Associate Professor in Africana Studies at the University of Arizona) [54]. This involved moving the project to a new VR platform every few years, which typically required recreating most of the VR environment from scratch because the different VR systems were not compatible and did not have import or export capabilities. This shows how even active and ongoing migration of a project from one VR system to another is challenging and requires significant resources. Another preservation challenge of current VR technologies is their dependency on server-based resources. The software packages that run VR headsets also rely on external servers for accessing user accounts. If VR headsets do not have "offline" modes, users will no longer be able to operate the VR hardware if the company's server (e.g., Oculus) goes down or the company ceases operation.

Interoperability was also identified as an important issue that had implications for preservation and reuse of VR content. One of the biggest challenges identified was the lack of concerted effort at the level of university campuses to communicate about VR projects and promote VR adoption in ways that would mandate interoperability. Different units on campus are creating VR content that may be useful for other units, but lack common interoperability standards and use an array of software and hardware configurations that may not be compatible. Thus, VR content may not be easily shared across campus units, not to mention between different institutions, if there is no coordination of interoperable VR solutions. One suggestion provided by participants to address this problem was to develop a database that would help identify who is using particular hardware/software configurations across campus, which would make it easier to adopt similar configurations and share content. The use of containerization tools (e.g., Docker), which bundle dependencies and system configurations together, could be useful for ensuring that VR projects are interoperable between units and institutions.

From these discussions, a set of considerations emerged that need to be taken into account when planning for preservation of 3D/VR. First, it was acknowledged that involving a range of stakeholder groups in preservation planning initiatives is essential for tackling preservation problems. In particular, software engineers should be involved in preservation planning in order to address the technical preservation issues. Second, standardization and adopting standards is critical. Developing common, sustainable preservation practices requires the standardization of preservation and access formats for VR and 3D. Third, preservation is closely connected with questions of interoperability and the ability to network and connect different virtual worlds. One participant pointed out that preservation is not enough and that virtual worlds also need to be interconnectable (i.e., use interoperable standards so that content can be shared and reused, and users are able to move between different worlds in VR), otherwise they will remain isolated and unused, inevitably becoming inaccessible. Finally, participants pointed out that other fields have been tackling similar issues around preserving complex configurations of visual information and computer software and hardware, such as audiovisual/moving image preservation and software preservation communities. Looking to strategies from these fields could also help the 3D/VR preservation community.

*3. Defining Strategies for 3D/VR Preservation*

Participants identified a range of possible preservation strategies for dealing with these challenges and preservation considerations. Selection and documentation were seen as important activities for ensuring the long-term preservation of 3D/VR content. Selection criteria for 3D/VR content, particularly in terms of making decisions about archiving low- versus high-resolution content was seen as essential, and participants saw an urgent need for best practices for appraising 3D/VR for archiving. This is complicated by the earlier point about identifying the "smallest preservable unit," because it is not always clear what needs to be saved throughout the lifecycle of 3D data (from capture to processing, editing, etc.). Participants agreed that preserving the "raw data" from the earliest phase of the 3D/VR project is important for future-proofing them, because even if the finished projects become inaccessible due to system obsolescence, they can still be rebuilt from their constituent elements.

What counts as "raw data" in research is still an open question being debated in many fields [55], and in the case of 3D data creation, participants pointed out that some "raw data," such as scanner data are typically in proprietary formats that have significant long-term sustainability issues. Documentation practices are also important throughout the lifecycle of curating 3D/VR content and they complement selection practices because they both provide information about the processes that created the 3D/VR content, how they interconnect, and the decision making process underlying their archival appraisal. Recent software released by Cultural Heritage Imaging for documenting the creation process of photogrammetry-based 3D projects was offered as a model for how documentation systems can be built into 3D/VR workflows in order to seamlessly capture key moments in the creation process [56].

In addition to these preservation strategies that are particular to 3D/VR content, preservation of 3D/VR can also draw on more general digital preservation approaches, such as emulation and migration. The use of virtual machines was suggested for running obsolete operating systems and VR software, but participants cautioned that one of the challenges would be supporting all of the drivers for the complex network of VR peripherals (e.g., head and hand tracking sensors, head mounted displays, etc.). Migration was seen as a potentially sustainable strategy for moving files out of obsolete systems to more sustainable ones. Planning for migration involves selecting VR systems that have the range of import and export functions necessary for moving files out of that system and into a new one at some point in the future. Based on the case studies considered in this forum (e.g., the Virtual Harlem project), if systems do not have export functions, migration will require rebuilding the virtual environment from scratch. This strategy also connects with the "smallest preservable unit" concept. As discussed earlier, there are issues with behaviors and physics tied to the game engine that limit the effectiveness of a migration strategy.

One final strategy discussed by participants was maintaining hardware and software in a fixed state (i.e., preventing automatic updates and hardware upgrades). While maintaining systems in a fixed state is only a short-term solution that is difficult to maintain in the long-term or scale-up for wider use, preserving software and hardware in this way could provide important examples for future emulation and migration projects. Because the hardware and software configurations for VR systems are typically very complex, having examples of running systems (for instance, in a computer museum context) is essential for understanding how they originally behaved through user interaction, which is necessary for developing future systems that accurately emulate earlier ones.

## IV. Summary and Discussion

The findings drawn from the discussions and presentations at this forum offer a broad view of the current concerns of this diverse community. The range of stakeholder groups is expansive and demonstrates a growing interest in immersive visualization technology across many fields and institution types. From the findings, we can identify and summarize a set of common challenges facing libraries and other information institutions that are implementing 3D/VR technologies.

Participants engaged in a lengthy discussion on issues associated with managing, using, and reusing VR content. The main challenges participants identified in this area included the need to develop reproducible workflows and documentation tools and procedures; concerns over research transparency and reproducibility, which are related to documentation concerns; and a complex array of ethical and legal issues that require further investigation.

For supporting documentation efforts, participants recommended the use of project management tools; keeping a journal or lab notebook to keep track of decisions made throughout the creation process; and storing data in open, well-documented file formats. Documentation is an essential component of ensuring research transparency and reproducibility for all forms of research data, but it is only part of the picture for 3D/VR. Participants also identified a set of practices that could help address the challenges of 3D/VR research data curation and preservation:

- Specify which elements of 3D/VR projects to save and at which levels of granularity.
- Define the level of quality at which types of 3D/VR elements should be saved.
- Identify the range of technological obsolescence and interoperability challenges, including: updating firmware and hardware; dependencies on third-party software; dependency on server-based resources or credentialing mechanisms; migrating older VR projects to newer systems; and Interoperability between VR systems and game engines.

From discussions on these challenges, participants defined a set of strategies and recommendations to address them:

- Involve diverse stakeholders in preservation planning to ensure that preservation plans will support the range of future uses.
- Involve software engineers in preservation planning to advise on the technical aspects of preserving hardware/software.
- Design and/or purchase systems with interoperability in mind to increase chance of long-term use.
- Actively monitor other fields, such as moving image preservation, that also preserve complex digital media.
- Adopt a lifecycle approach to managing and preserving 3D/VR content.

Techniques for preservation defined by participants to support these strategies include: planning from the beginning of a project for eventual migration and emulation; maintaining hardware and software in a fixed state, as documentation to guide migration and emulation; and recording videos in order to document fully-functioning VR environments. Beyond documentation and preservation concerns, management of 3D/VR content also involves negotiating ethical and legal issues. Some of the key areas identified that need additional work include: concerns about scanning cultural heritage sites and artifacts and claiming ownership of resulting files; understanding the impact of 3D scanning on original artifacts, and the owners or custodians of original artifacts; and establishing protocols for protecting culturally sensitive materials.

Many of these techniques and challenges are not unique to 3D/VR, but overlap with digital preservation concerns for preserving other types of complex digital objects. The field of video game preservation is also concerned with exploring emulation and migration as preservation strategies [57, 58, 59, 60]. For 3D/VR, emulation and migration strategies appear to be more difficult because of the complex array of hardware peripherals and drivers that constitute a VR system. Migration to new software/hardware environments may be particularly difficult. For instance, the case of the Virtual Harlem project, discussed earlier, suggests that migration may be so difficult that researchers will choose to entirely rebuild the virtual environment on a new VR platform. One hope is that the building blocks of VR environments will be interchangeable, following shared technical standards, so that even if the virtual environments need to be recreated in the future, much of the underlying content will be reusable.


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3D/VR also shares similar concerns with the field of *time-based media conservation* [61] in terms of the need to document complex configurations of audio-visual media technologies as they function in their original context, via photography, video recordings, diagrams, etc. In time-based media conservation, the resulting documentation can help guide conservators as they take steps to conserve and prepare the work for exhibition in the future, as part of a critical discourse and investigation of the meaning of media and performance-based art [62] or to match emulated or migrated versions to the documented originals [63]. Similarly, documentation can help emulation or migration efforts for VR environments to make them renderable in the future. Others in the digital preservation field have suggested that the documentation of complex digital objects may be more valuable to future archivists and historians than preserving working versions of the original software [64]. The nascent field of 3D/VR preservation should look to these established fields for guidance and collaboration.

## V. Conclusion

The overriding theme across the findings from the Forum is the importance of interinstitutional and interdisciplinary collaboration. Confirming what we had assumed going into this project, it is clear that many of the challenges of 3D/VR can only be solved through systematic and concerted effort across multiple stakeholder groups and existing subfields of preservation research and practice. Furthermore, 3D/VR is not limited to a niche area. As we can see from the range of participants and the diversity of uses they identified, there are wide applications and growing mainstream acceptance in many contexts. Further collaboration through future forums and working groups could and should generate standards and best practices for application across the broad 3D/VR community. These need to be specific enough that they can offer real guidance to stakeholders of varying capacities, but flexible enough to be useful for a range of applications and disciplinary practices.

While the findings from the Forum suggest a variety of techniques and strategies for addressing the challenges identified, there is still much more work that needs to be done to establish standards and best practices. In addition, developing tools for supporting 3D/VR throughout the research or educational lifecycle is critical. Such tools should include:

- Project management and documentation tools.
- Universal 3D viewers that are able to integrate with diverse VR equipment and 3D repositories.
- Sustainable, preservation-quality file formats for 3D/VR.
- Open platforms for hosting and preserving 3D/VR content.

There are a number of other projects that are addressing some of the most pressing challenges in the field of 3D and VR research and teaching, including Community Standards for 3D Data Preservation (CS3DP), discussed earlier; Building for Tomorrow, an additional IMLS-funded project that is developing guidelines for preserving 3D models in the fields of architecture, design, architectural archives, and architectural history; the 3D Digitization Project at the Smithsonian Institution's Digitization Program Office, which is developing software, workflows, and metadata guidelines for a variety of 3D creation processes; and the Library of Congress's Born to Be 3D initiative, which has started convening experts in the field to look at the preservation challenges of "born digital" 3D data (e.g., CAD models, GIS data, etc.). The LIB3DVR project team plans to continue to collaborate with members of these projects, and is confident that through these initiatives, useful standards and best practices will emerge to help librarians, digital curators, and other information professionals address the complex challenges of preserving and curating 3D/VR for academic use.

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