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DIGITAL REVIEW

The Emerging Uses of 3D Technologies in the Practice of Repatriation and Revitalization

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Overview
Digital technologies, including 3D digitization and replication, are increasingly integrated into repatriation-related work by museums and Indigenous communities. Repatriation laws began being adopted in the United States at state level in 1976, followed by federal repatriation laws in 1989 with the National Museum of the American Indian (NMAI) Act, which applies only to the museums of the Smithsonian Institution, and in 1990 with the Native American Graves Protection and Repatriation Act (NAGPRA). Early repatriation, therefore, was in the predigital age, but the use of computers and databases, including digital imaging, email, and file-sharing, has had a significant impact, first with 2D digital technologies and more recently with the incorporation of 3D digitization. These, and the creation of surrogates of archival and object collections, have led to an explosion of information-sharing between museums and Indigenous partners. 2D digitization and 3D digitization and replication, in consultation and collaboration with Indigenous communities, are emerging as important tools alongside repatriation efforts—not in lieu of repatriation but as supplements to mutual interests that go beyond it. Here, the experiences of the Smithsonian's National Museum of Natural History and others are offered as examples of such new applications of 3D in the context of repatriation and beyond.

Digital 2D Technologies and Repatriation

In the early 2000s, Tribal repatriation representatives consulting with the Smithsonian's National Museum of Natural History told me their main reason for visiting the museum was to take photos of items so they could share them back home and consult more widely in their community. Thus, they were excited to learn that the museum could provide CDs with digital images of all the collections. Their ability to share images, with multiple and adjustable views, taken for granted by most today, was a major improvement over the limited information of the collections lists and summaries required by the Native American Graves Protection and Repatriation Act (NAGPRA). Beyond relationships with Indigenous communities, and sometimes at odds with them, museums have embraced 2D digital approaches for making their collections more widely accessible by posting images to the web for the general public (e.g., https://artsandculture.google.com/), moving toward "democratization" of the collections through open access with limited or no restrictions.

The practice of making 2D physical or digital copies of archived documents and images available to Tribes is not new, but it has been rebranded in the age of repatriation as "knowledge repatriation," "digital repatriation," "visual repatriation," or "virtual repatriation," none of which is truly repatriation of ownership, since control of the originals is not transferred (see the comments of Enote in Bell et al. 2013; Csoba DeHass and Hollinger 2018). However, digital media have allowed for a dramatic increase in consultation, exchanges, shared stewardship, and collaborations for cultural heritage collections and their surrogates in repatriation and other areas of mutual interest for source communities and museums (e.g., Emmitt 2022). In addition to Tribal representatives reviewing digital images sent by the museum or

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posted to online databases, it is now common for Tribal representatives to send museums digital images of specific items when they are searching for related object types.

The Emergence of 3D Digital Technology in Repatriation

3D technologies expand the engagement between museums and communities and show potential for future applications—both 3D digitization and replication (Cooper 2019). The creation of 3D physical replicas of cultural heritage items is not new to the museum world, since casting and making paper squeezes (wet paper pressed into object surfaces, like petroglyphs, to make a negative impression) have been common practice for hundreds of years. But the addition of 3D digitization and replication is creating an explosion in collaborative opportunities for museums and Tribes, aiding with their repatriation efforts and beyond. 3D capture techniques range from rare, high-cost computed tomography (CT) and laser scanning to more common, low-cost photogrammetry with smart phones (Magnani et al. 2020). In parallel, the physical production of cultural heritage surrogates has also begun to involve 3D printing, ranging from crude models made of thermoplastics such as plant-based polylactic acid (PLA) filament to detailed prints made of petroleum-based polymers and metals. Color can sometimes be incorporated in the printing process to precisely replicate the colors and textures of the originals. Less commonly, subtractive processes like the computer numerical control (CNC) milling of materials such as wood, metal, stone, and bone have allowed matching original materials. This is often combined with hand-painting and the addition of composite components by model makers for more precise replication.

As the incorporation of 3D applications is relatively new to the repatriation world, most projects have been experimental, or pilots made possible by increasing trust and a collaborative spirit between Indigenous communities and collection repositories. The Repatriation Office of the Smithsonian's National Museum of Natural History (NMNH), driven by requests originating from partner Tribes, villages, and clans, has pioneered the use of 3D digitization and replication for cultural items, supporting educational interests while expanding access and shared stewardship. The NMNH, working with experts in Smithsonian Exhibits, the Digitization Program Office, and the Museum Conservation Institute, and in close consultation with communities, has made replicas of funerary objects, sacred objects, and objects of cultural patrimony, typically after the items have been formally repatriated. Rather than a substitute for repatriation, replication has served as a supplement to repatriation, allowing the museum and Tribes to show online 3D digital models of objects and to exhibit and handle physical copies for the continued educational aims of both the museum and Tribes. The replica collaborations that have emerged have naturally grouped into four main kinds of collaboration: (1) items repatriated but replicated for educational purposes, (2) items not subject to repatriation but still replicated for educational purposes, (3) items not owned by museums but replicated for a Tribe's educational and revitalization needs, and (4) items replicated to fully replace a sacred object or object of cultural patrimony for cultural revitalization that is not a true repatriation. The examples below highlight these sets of 3D applications.

Items Repatriated and Replicated for Educational Purposes

In 2005 the Smithsonian's NMNH repatriated a Tlingit Killer Whale Clan Hat to the Dakl'aweidí clan. Years later we were approached by the clan to digitize and replicate the object, through wood-milling, to make a copy for the museum's exhibition (Hollinger et al. 2013). Unlike the original, which contains the spirits of Ancestors, the replica is not a ceremonial object, but in a shared stewardship agreement with the clan it can be removed from exhibit on request to be danced as regalia (Figure 1), a symbol of the clan, when dance groups visit the DC area. In another collaboration, the Munsee and Delaware Tribes asked the museum to make 3D prints of a seventeenth-century pewter pipe, an unassociated funerary object, so the original could be reburied while educational replicas could be retained by all three Tribes and the museum. Another project involved the 3D printing and milling from wood of dozens of shamanic funerary objects repatriated to the Tlingit Hoonah Indian Association for both the museum and the Tribe to use for educational purposes while avoiding the potential spiritual and chemical hazards of handling the originals. The University of Maine's Hudson Museum recently completed a similar project in which they worked with Tlingit and Haida to 3D print and paint a replica of a Tlingit Frog Helmet

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Figure 1. Joshua DeAsis dances wearing the replica hat. (Photograph by Eric Hollinger.)

before the original was repatriated (Faulkner et al. 2023). In these examples, the original items were repatriated to continue their spiritual and cultural functions, while duplicates allowed both the museums and the Tribes to continue their use for educational purposes.

Items Not Subject to Repatriation but Replicated for Educational Purposes

Other 3D collaborative projects have involved utilitarian and other items that do not fit repatriation categories under the law. These, again, have been replicated for Tribes to use for teaching purposes and to put into use for cultural revitalization. Partnering with Tlingit representatives, the Smithsonian CT-scanned rare Tlingit throwing boards, *shee aan*, and then 3D printed high-strength nylon replicas (Hollinger and Partridge 2017) that are now serving to teach youth in culture camps about this forgotten hunting technology and to inspire carvers to begin making them again from wood. In a similar collaboration, after repatriating ancestral remains from the NMNH in 2017, the Yupik Native Village of Igiugig President AlexAnna Salmon continued the relationship with the Smithsonian and asked for six items to be 3D replicated to exhibit in their planned cultural center and for use in cultural revitalization. President Salmon had moose and caribou bone and wood shipped from their area to the Smithsonian so the items, which included a comb and spoon made of bone and a dish, throwing board, and dance mask made of wood (Figure 2), could be CNC milled from local materials. A visor for preventing snow blindness was 3D color-printed, as was an additional copy of the mask to serve as a model for the community to paint their wood replica.

Items Not Owned by Museums but Replicated for Tribal Education and Revitalization

Collaborations in 3D replication have also involved Tribal property that has never been in a museum, so the technology and expertise of the museums can serve the community. For instance, Tlingit Teikweidi clan leader Daniel Brown asked a team of 3D specialists from the Smithsonian and the University of South Florida's Center for Digital Heritage and Geospatial Information to make a replica of the clan's Mother Bear Hat, which is said to be hundreds of years old, so he could use it for teaching in schools and other contexts without putting the original at risk. Brown worked with the team to digitize the hat in 2019 using a structured light scanner, and the University of South Florida's Jorge Gonzalez then

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Figure 2. Milled spruce replica, *left*, with original dance mask from Igiugig, Alaska. (Photograph by Walter Larrimore.)

processed the digital model so various wooden, copper, and shell parts of the hat could be 3D printed separately in plastic. A half-scale model was printed and sent to Brown for his review and consultation. Gonzalez then printed a full-scale model and sent it to the Smithsonian, where inlays were shaped from real shell and copper, based on the printed pieces. Brown planned to travel to the Smithsonian with the original hat so they could work together to assemble and paint the replica using the original for a model, but Brown fell too ill to travel, so retired Smithsonian Exhibits model maker Carolyn Thome and I flew to present the printed hat to him in a hospital in Alaska. We then spent the next three days in the Brown family's kitchen with the original hat, assembling and painting the replica and attaching hair, shell, and copper (Hollinger et al. 2024). The only real difference from the original was Brown's request to paint it in red, a color hidden beneath a more recent overpainting of brown on the original. Once the replica was finished (Figure 3), it was presented to him in his hospital bed, completing his last act as Teikweidi clan leader before he "walked into the forest" three days later; his goal to have a replica to teach with, and demonstrate the potential for 3D technology to serve cultural preservation and perpetuation, was fulfilled. Although not a repatriation, this collaboration highlights the power of 3D to benefit communities in ways that extend many of the intents and goals which are integral to repatriation.

Items Replicated to Replace an Important Object

3D digital and physical replicas may not be expected to fully take the place of original objects, but they can offer surrogates that fulfill or expand many of the roles and qualities of originals for museums and, under certain circumstances, even for the communities from which items originated. For instance, the Tlingit Kiks.ádi clan of Sitka asked the NMNH to digitize a worn and broken clan hat in the form of a sculpin fish in the Smithsonian's collections, digitally repair the hat, and then mill a new hat that could be danced and used in ceremony. The project merged traditional cultural protocols for making clan crest objects, called *at.óow*, with twenty-first-century technology to make the new hat (Figure 4). The Tlingit community then consecrated it in ceremony as a sacred object and an object of cultural patrimony (Hollinger 2019, 2022; https://www.youtube.com/watch?v=y7YzLlbVSN4). Although technically a replica of the broken original, once spirit had been put into the hat, it became more than a replica: it was the new, restored clan crest hat, ready for the religious functions such hats serve in Tlingit society. This collaboration demonstrates that we cannot make assumptions regarding what a Tribe may or may not feel is an appropriate use of 3D digitization and of the replicas produced using it.

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Figure 3. 3D printed replica, *left*, and original Mother Bear Hat of the Teikweidi clan. (Photograph by Eric Hollinger.)

Thinking about 3D Digital and Physical Replicas

As these collaborations illustrate, there are many case-specific responsibilities and challenges for caretakers of objects, 3D specialists, and cultural authorities and knowledge bearers. They require shared goals, open consultation, and ethical and legal responsibilities that may be unique to the realm of 3D cultural heritage. An international group of 3D heritage specialists and Indigenous representatives, led by Medeia Csoba DeHass, has been researching these issues to identify and share best practices for responsible work in this emerging field. They suggest incorporating Collective benefit, Authority to control, Responsibility, and Ethics (CARE) principles, recognizing Indigenous data sovereignty and adopting a coproduction of knowledge framework (Csoba DeHass et al. 2025; also see Bollwerk et al. 2024). Exactly what forms that might take will vary, depending on the many factors particular to each collaboration, but it is becoming clear that Indigenous researchers themselves are developing more of their own capabilities and protocols for digital capture and model use and strengthening their independence and control of the process. The Blackfoot Confederacy's Blackfoot Digital Library and Mootookakio'ssin (Distant Awareness) project is one example: Blackfoot elders and students used photogrammetry and reflectance transformation imaging to digitize Blackfoot items in several British museums and then post them to a microsite for increased access with language and cultural-context information (https://mootookakiossin.ca/about/#The%20Project_About). Similarly, the Northwestern Band of Shoshone has begun digitization of collections far from home to incorporate into physical and cultural contexts using virtual and augmented reality (James Cawley, personal communication 2024; also see Cobb and Azizbekyan 2024). In addition to these US and Canadian Indigenous communities, the Indigenous Sámi of Sápmi (northern Scandinavia) have sent their own teams of digitization and cultural experts to US

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Figure 4. The new Sculpin Hat, replicated for the Kiks.ádi clan using 3D digitization and fabrication technology. (Photograph by James DiLoreto.)

and European museums to digitally recollect cultural items, including drums of religious and historical significance sought for repatriation (Magnani et al. 2018, 2023).

These efforts are the vanguard of communities exercising sovereignty in their use of 3D digital technologies to fuel cultural revitalization (Figure 5). They and the collaborations highlighted above show that 3D digitization and replication in the service of repatriation and beyond demonstrate repatriation is about much more than emptying museums and tallying completed returns. Museums and Tribes working together with 3D tools can discover mutual interests in cultural preservation and perpetuation for future generations, while forming new partnerships nearer to those that should have existed if repatriation had not been necessary. In the future, with the increasing power of computing, decreasing costs of the technologies, and expanding expertise with the methods, we can expect to see, as we have with 2D digitization, the increased production and sharing of 3D digital files and models, both digital and physical, of cultural heritage materials. With them will be the increased responsibilities of museums and Tribes to build trust and work collaboratively, and to do so in close consultation that extends beyond 3D and beyond repatriation.

The small but growing community of museum and Tribal specialists has been exploring the new frontier of 3D technology and its potentials for use in repatriation and cultural revitalization. As we share our experiences and stories of how the technology has been employed, we are continuously surprised by the inventive new ways that Tribes seek to put 3D replicas into their service. Uses that a museum would dare not propose are being sought by Tribes because they recognize the potential of the technology. For instance, the demonstrated value shown by the Killer Whale Hat, Sculpin Hat, and Mother Bear Hat projects have inspired many Tlingit clan leaders to have their precious clan hats and other objects digitized so the files could be archived as security against loss. Given that fires have destroyed many important Tlingit objects over the years, they value 3D digitization as a form of insurance. At the same time, they and other Tribes recognize there are new risks with the technology, particularly that it could be misused for digitally appropriating their culture, such as the unauthorized commercial production of replicas of their cultural patrimony. Considerations like these demonstrate that 3D digitization and replication require a great deal of responsibility, trust, and thoughtful collaboration to help them realize

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Figure 5. Tlingit Stax'héen Tláa (Stikine Mother) Luella Knapp, of the Naanyaa.ayi clan, using a structured light 3D scanner at the Smithsonian's Museum Support Center to digitize the prow of a 13.7 m long Brown Bear Canoe that belonged to the Naanyaa.ayí clan, whose spokesman was Chief Shakes. (Photograph by Walter Larrimore.)

their potential while minimizing risks in these renewed relationships. In this way, while 3D digitization and replication of cultural heritage are a newly emerging field, it is emblematic of all of repatriation, in that it is anchored in rebuilding trust, renewing relationships, and establishing collaboration for mutual interests.

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