3D Heritage Preservation and Indigenous Communities in the Circumpolar North

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We examine theoretical and practical applications of 3D technology in digital and physical preservation of Arctic and Subarctic Indigenous cultural heritage. A lasting legacy of colonialism in the Circumpolar North is the disconnect between local communities and their material heritage housed at memory institutions around the world. While collection methods varied, collecting activity was entrenched in colonial power relations expressed in the "researcher and the researched" paradigm. With diminished access to their material culture, loss of traditional knowledge ensued, which affected both local communities and global discourse. While postcolonial engagements have been exploring avenues for returning collections knowledge to origin communities, geopolitical realities of the Arctic have limited these efforts. The expenses of long-distance Arctic travel and the decentralized nature of communities, the lack of Indigenous-run museums, and the fact that Indigenous belongings are widely dispersed make it challenging to develop lasting and comprehensive approaches. Many museum objects remain unidentified or misinterpreted due to disengagement between Indigenous communities and ancestral possessions. Recent developments in 3D technologies can re-establish origin and descendant community access to collections, develop community-engaged collaborations and offer decolonizing approaches to collection management, acquisition, and engagement practices. Digital 3D models and physical replicas offer alternative modes of access and opportunities for Arctic and Subarctic communities. Rapid development of digitization and replication technologies reveals a potential for empowering community heritage restoration and perpetuation as well as strengthen abilities of distant stewardship institutions to improve access, improve community collaborations and enhance their capacity for cultural preservation.

Introduction

Using new technologies to care for Indigenous collections in museums has a long-standing history in museology. Museum preservation, conservation, and education have all benefited from digitizing collections and using technological innovations to better understand and care for

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collection pieces (Turner, 2016). Yet, using digital platforms to connect museum collections with origin communities based on the principle of shared curation has not yet become a part of standard museum practice (Brown & Nicholas, 2012: 320; Rowley, 2013: 23; Srinivasan et al., 2009). For this reason, community-engaged collaborations that offer decolonizing approaches to collection management, acquisition, and outreach need further discussion to succeed in translating theory into practice.

3D technologies offer great promise to bridge the disconnect between museum collections and origin or descendant communities. Moreover, the separation between Indigenous collection pieces housed at memory institutions (Stainforth, 2016) and their ancestral communities results in a rupture between the tangible and intangible aspects of Indigenous cultural heritage. Strategically using 3D technologies can assist in narrowing, or even eliminating, this divide. On the most basic level, using 3D technologies in heritage preservation consists of creating digital models and printing replicas from those models. When 3D is incorporated into a comprehensive heritage preservation plan that places collaborating with Indigenous communities into its center, 3D technologies can engender, support, and complement physical repatriation. In this context, using 3D technologies does not replace physical repatriation, rather, it serves as one aspect of the repatriation process providing access to ancestral possessions and by extension, to traditional knowledge.

In Arctic and Subarctic Indigenous communities, physical distance and high travel costs limit meaningful physical access to collections and memory institutions. In the past decades, institutions often solved these problems through seeking tribal partnerships and providing access to select groups of Elders and knowledge bearers who traveled from remote areas of the Arctic to spend a few days with the collections (Crowell et al., 2010). The increased interest in developing partnership with Indigenous communities was spurred in the United States by federal repatriation legislation requiring museums to inventory their holdings, consult with tribes and repatriate specific types of collections to federally recognized Native communities, including those in Alaska. Those community members visiting the ancestral possessions carried knowledge about them back to their communities as information about the existence of Arctic collections became available. In the past decade, with growing assertion of Indigenous self-determination in Arctic and Subarctic regions, Indigenous artists and historians, tribal organizations, and Indigenous communities took matters into their own hands and systematically explored well-known collections. As knowledge of these collections spread from community to community, specifics on what these collections contained was also shared. Bringing representatives to museums was a novel approach to addressing the acute problem of disenfranchised collections and imbuing them with cultural knowledge. At the same time, travelling to collections was still limited to a few participants and entailed a limited experience. As we discuss below, 3D technology provides alternative heritage preservation practices that allow more community members to have a personal engagement with the pieces with less gatekeeping or without a limited selection process. Moreover, 3D allows for the presentation of Arctic Indigenous material heritage in culturally appropriate contexts that are governed by community specific understanding and interpretations.

Colonialism as Arctic Legacy

Colonialism affected Indigenous peoples and cultures around the world including the Arctic and Subarctic. As communities continue to grapple with the lasting legacies of postcolonialism that are both overarching in general effects and idiosyncratic to the location, they draw on their own culturally specific coping mechanisms and strategies. In Arctic and Subarctic Indigenous communities, the process of reconnecting and meaningfully reincorporating traditional items now housed at museum collections is complex and fraught with challenges that are rooted in the colonial history of the Arctic. As in most colonial encounters, travelers, the military, missionaries, collectors, and members of the colonial administration removed material culture from Indigenous communities across the Arctic. Some of these removals were negotiated and obtained legally, but many of them were not (Cole, 1985; Killion & Bray 1994; Pullar, 1995). Whether it was taking items from graves and ceremonial places, trading them below value through local people who had no authority to sell them, as for instance in the case of clan ownership; or collecting items that were destined to be destroyed according to local conceptualization of these items' role in the universe, the outmigration of culturally significant material culture from the Arctic and Subarctic was relentless and pervasive (Cole, 1985; Lindsay, 1993).

Both ethnographic and archaeological pieces were removed from Arctic communities and assembled as collections in museums and heritage institutions. Most of these memory institutions were located in non-Arctic regions of the world, often in different nation states and on different continents than the origin communities. While knowledge about the existence of these collections was preserved in the memory institutions where curators, researchers, and museum personnel cared for these Arctic Indigenous items, the connection to the origin community was often lost. The detachment from the origin communities was further exacerbated by the practice of inter-museum trade that aimed at diversifying collections to have a fuller representation of the World's cultures. As the cultural knowledge about a specific piece or a group of items was lost, pieces that formed a cohesive intellectual unit based on Indigenous epistemology were separated and dispersed around the world. The detachment from the communities that produced and meaningfully interpreted these items created knowledge loss on both local and global scales. Local communities no longer knew about the existence of the material heritage of their ancestors, whereas heritage institutions were no longer cognizant of the intangible heritage attached to their collection pieces they were caring for.

As with all aspects of post-colonialism, national and international legislation and agreements aimed to address and ameliorate harm caused by past collection practices helped, but did not fully rectify the lasting legacy of cultural loss on the local scale. U.S. Federal repatriation legislation (1989's NMAI Act and 1990's NAGPRA) and the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP Articles 12 & 31) of 2007 addressed issues of Indigenous material cultural heritage including preservation and repatriation (Hollinger et al., in press). Although, with the exception of rare cross-border cases, U.S. laws do not affect international collections, UNDRIP is not a legally binding international agreement, and Canada lacks national repatriation legislation, repatriation of certain material Arctic Indigenous heritage can still take place (e.g. Grande 2017: 270-273; Mullen, 2003). Under U.S. legislation, only items in specifically defined categories are eligible for repatriation. These include human remains, funerary objects, sacred objects and objects of cultural patrimony and only those items shown to have been illegally alienated must be returned. While physical repatriation is an important step in reuniting the once removed material heritage with its origin or descendant communities, in the Arctic and Subarctic regions the situation is complicated by the challenges of Arctic realities.

Items that are physically returned to Arctic regions and into the custody of the legally designated representative of an Indigenous origin or descendant community may still never be reunited with the members of the said community (Csoba DeHass & Taitt, 2018). Many Indigenous communities in the Arctic are decentralized in terms of geographical and political autonomy. Villages within a cultural region may spread over thousands of miles and legal representation in NAGPRA affairs can lie with several different organizations and appointees. As there are very few local museums and repositories in villages and rural, off-the-road Alaska Native communities that are equipped to care for repatriated items, these pieces often end up in larger museums, repositories, and memory institutions in Anchorage or in regional hubs.

The cost of travel in the Arctic is exorbitant and continually rising. Large distances, limited travel options, high price of fuel, and the culturally specific tendency for travelling in groups can all pose challenges, and as such, make it difficult to access repatriated collections that are deposited at centrally located facilities (Csoba DeHass & Taitt, 2017a). While "centrally-located" may imply easy-access by most stakeholders, in the Arctic, it often translates to the opposite. When people travel from rural communities to hubs, they often do so for a specific reason such as shopping, medical appointments, board meetings, or specific events. While these trips can accommodate meeting with family, travelers usually have very little free time. If people do make it to a heritage institution, they do not have more than a couple hours to spend with the repatriated pieces. As a result, most community members are either unaware of or have never connected with the repatriated items. In essence, community members often do not have easy and sustained access to these repatriated collections. While repatriated items are legally in the possession of the descendants, there is no meaningful engagement that allows for the continued reinternalization of the items as a community. This lack of repatriation to the cultural context detracts from the practical utilization of intangible cultural heritage as a source of traditional knowledge that informs contemporary Indigenous self-determination in the Arctic.

A reality of the legal and administrative organization of Alaska Native entities, including regional associations, village councils, and corporations, is partially due to the Alaska Native Claims Settlement Act (ANCSA) of 1971 and Federal Indian policy. Just over 40% of the 562 federally recognized tribes of the United States are located in Alaska (Williams, 2009: 2). In terms of heritage preservation, this translates to a great deal of autonomy from other tribal entities when it comes to decisions regarding material heritage. As there is no overarching policy either in Alaska or, on a more general level, in Artic regions that are jointly created and adopted by most Indigenous organizations and entities, there are significant differences in terms of access, involvement, and input when it comes to working with collections at memory institutions.

Museum Practices Preceding 3D Technology

Community outreach and museum programming to collaborate with origin and descendant communities predates digitization and digital technologies used for preservation. Cultural revitalization has been a major driving force behind forging partnerships between Indigenous communities and memory institutions (Fienup-Riordan, 2005). Printed catalogues of 2D images were often widely shared with communities in the hopes of creating long-lasting connections, despite the fact that the cost of printing high resolution color photographs seriously limited the number of copies that could be produced.

The reburial movement of the 1970s and 1980s that culminated with the passage of federal repatriation legislation in the form of the National Museum of the American Indian Act in 1989 and the Native American Graves Protection and Repatriation Act in 1990 brought a paradigm shift to museums with the idea of physical repatriation that is not merely a possibility but a requirement (Hollinger et al. in press). Museums were obligated to inventory and share information about their collections with communities. Collection doors gradually opened to origin and descendant communities (Eaton, 2009) to work directly with collection pieces. As communities started to come to terms with the idea of their ancestral heritage being returned as well as learning about the everyday museum reality where material heritage is scattered around the world in various collections, the key concept of access emerged (Haakanson, 2015).

Knowing what is in a collection is challenging for both Indigenous communities and curators alike, although for different reasons. The former does not know where their heritage pieces may be located, while the latter may not fully be aware of what they have in their collections. For this reason, it is easy to see the appeal of digitizing basic catalog information that can be made available to the greater public online. Having relatively easy access to the basic collection information has the potential to greatly increase access, yet it is very unlikely to happen when such databases are not curated. Internet-based database search is a learned skill that most end users need to develop. Curated digital exhibits and digital humanities projects, regardless of their level of interactivity, can offer guidance on the nature of collections while drawing attention to certain items. The growing interest in curated digital projects are centered on harnessing the power of easy access and wide-reach that can yield rich network and metanetwork connections (Glass & Hennessy, in press). Yet, with Indigenous collections, culturally inappropriate access to material heritage remains in the center of the discourse (Anderson et al., 2018: 23; Christen, 2009; Hennessy, 2009; Were, 2014). The challenge of balancing knowledge-sharing, digital preservation, and culturally appropriate access is far from being resolved, partially, due to rapid developments in technology that require constant re-interpretation of previous agreements and best practices.

The widespread availability of using 3D technology for heritage preservation is largely possible due to the lucrativeness of the video gaming industry that continues to be the push behind ongoing, rapid technological development and making hardware and software affordable to the mass market. In heritage preservation, 3D technology can cover a variety of applications. It has been used for creating digital models of buildings and landscapes that were threatened by sociopolitical realities (Zamani project, 2015). In addition to preservation it can also digitally reconstruct historical structures (Hess, 2013; Neumann, 2013; Younes et al., 2017) and virtually bring information to users about historical structures from around the world (Levy & Dawson, 2006). Archaeology has been using 3D for both site and artifact documentation for decades. 3D laser scanning is particularly amenable to the hard-surface material archaeological excavations produce and has been used to document entire collections. Unlike archaeological collections, ethnographic collections that often consist of soft material and composite pieces are more of a challenge. Digital 3D models, particularly when combined with augmented reality, allow for cultural contextualization and can offer new opportunities for collaborations that bring together culturally appropriate outreach, preservation, and place-based education.

In addition to creating 3D digital models in origin communities or in collections, printing has also been used as part of a community engaged heritage preservation strategy. With permission from origin and descendant communities, physical repatriation of material heritage can occur alongside digital 3D preservation and printing replicas of the original items (Hollinger et al., 2013; Hollinger & Partridge, 2017). While a replica can remain with the memory institutions and be used to support institutional mission, original pieces return to their communities. The practical applications of 3D printing in a heritage preservation context suggest a broader impact as each Indigenous community internalize the concepts of 3D printed replicas through their cultural logic and decide on their appropriate use.

3D Digitization and Replication Technologies

3D digitization and replication technologies offer new and wider opportunities for addressing cultural heritage preservation and perpetuation issues. 3D digitization adds to the positive attributes of 2D digitization by making objects more informative then merely a collection of 2D images. In the past, viewers would have to flip from still image to image on a CD or other media to experience different perspectives and angles on a single object. Photos taken for documentation of an object or for use in a publication often omitted details that were significant for origin community members (Csoba DeHass & Taitt, 2017b). The inside of a hat, the weave used to finish off the rim of a basket, or the carving marks on the back of a mask carry important cultural information that are difficult to access through 2D images. With 3D digital models the user can turn and spin an item and experience the changing light and shadow of different views as if the object were in their hands. The model can also be enhanced and manipulated to highlight or bring out features that are difficult to see even on an in-hand original. Multiple viewers can experience an object simultaneously thousands of miles from one another and can remotely offer comments and correction to the record of the item. In the case of models produced using CT-scans, even the interiors of objects, invisible by any other means, can be made accessible to the viewer revealing information critical to understanding its manufacture or use (Hollinger, in press).

In addition to narrowing the distance problem, digital 3D models offer the ability to access items that may be problematic for handling. Fragile items at risk if moved, or items that require climate controlled or high security conditions, can be examined in a 3D model form repeatedly without further risk to the object. In some cases, the objects themselves may pose a health hazard to those handling them because of pesticide treatments or hazardous substances applied during their original manufacture. For instance, the bright red paint seen on many objects from the North West Coast is cinnabar-based, mercury sulfide, which poses health risks for handling. Still other items may have an issue when direct physical contact or proximity to an item poses spiritual hazards. Access to 3D digital models offers options for experiencing the items without compounding the risks to the objects or to the handlers.

The use of 3D digitization and replication can also be used to supplement the repatriation process. At its most basic level, the term 'repatriation' means the return to the country of origin and it has been used to refer to spies, illegal immigrants, POWs, and stolen artworks. In the context of cultural heritage, it has usually been reserved for the tangible human remains and objects being returned through a legal means for reburial, use in ceremonies, or other purposes of the descendant community whose rights are restored in the process. These returns are complete transfers of ownership and control of material items and remains and anything short of that complete control is viewed by some as something less than repatriation (Enote, 2013).

But the term 'repatriation' has also been applied to processes of returning copies of archival records and photographs (Christen, 2011; Krupnik, 2000) or 2D digital images of collections and records (Bell et al., 2013). These forms of information sharing by museums have all increased with the aid of digital technologies, and although they do not usually entail full restoration of ownership and control, they may still be best viewed as forms of digital repatriation. 3D digital files, as surrogates of physical items, can also be grouped in this approach.

In addition to the opportunity of being part of the repatriation process, Indigenous communities also see the benefit of 3D modeling. Repatriated items that are entrusted to a repository outside of the origin community due to lack of appropriate local facility and collection care can be 3D modeled and shared with community members. Engaging with a 3D model or printed replica provides personal access to ancestral heritage embedded in the original piece. When discussed within the community, the series of personal experiences can lead to a collective interpretation of the repatriated piece. Through these processes, the repatriated items can be reintegrated into the cultural reality of the community, despite fact that they are stored at a remote location.

In all its forms, digital repatriation complements and has the potential to go beyond physical repatriation to increase community access and aid in cultural heritage preservation. It facilitates access across great distances which are always an inhibiting factor in the Arctic and Subarctic. As access to computing technology and the internet has expanded, so has the capacity for digital communication of cultural heritage information. Indigenous communities and curating institutions have made use of the technology to increase community engagement with distant collections and archival records leading to a number of collaborations aimed at cultural heritage preservation.

Digital 3D Models

Digital 3D models serve multiple purposes in heritage preservation. Due to the relative newness and rapid development of the technology, we probably have not had an opportunity to explore all possible areas and applications of heritage work that can benefit from using 3D. Furthermore, as all aspects of 3D technology are tools that can be used to solve issues and offer up innovations, they are highly adaptable to cultural context and specific project goals.

In general, 3D models have two main parts. The first is the 3D point cloud that serves as the structure of the model. This data set carries the information needed to print replicas, to complete measurements, to run programs that can synthesize a large amount of information such as similarities, to edit the model, or to use the model to reconstruct pieces missing from the physical item. The second part is the 3D model that has a structure and a surface, which makes it closely resemble its physical counterpart. The 3D model can be displayed in a viewer, embedded into a variety of content management software, or uploaded to an online publishing platform such as Sketchfab (2018). Displaying the 3D model does not give access to the point cloud, and as such, does not make it possible to reproduce the item. This is a crucial element of working with 3D models in heritage preservation, as currently there are no best practices developed for 3D technology and Indigenous material heritage. The lack of regulations, guidelines, and widely-shared best practices regarding 3D modeling of Indigenous heritage makes it one of the most important roles of researchers to thoroughly explain the nature of 3D models and the possible dangers of misuse and misappropriation to the collaborating communities.

The most basic way to experiment with digital 3D models is to use an application, such as Qlone, that renders the model within a few seconds. Many 3D modeling applications use a structure-from-motion algorithm to render the model, but there are also applications, such as Skanect, that pair a scanner with a mobile device. Using mobile applications to create 3D models can limit the size of the item being modeled and the applications may also have limited editing capabilities. Moreover, the geometric accuracy of the models produced with such applications are generally lower than those produced with photogrammetric software or high-quality laser scanners. Yet, the possibility of producing models quickly even by first-time users of the applications makes up for these limitations. 3D modeling applications usually work on smart phones or tablets using the built-in camera to view the physical item. Because 3D apps are highly mobile and can be easily deployed in origin communities, rural areas, in collections, or in the field, they can be an ideal tool to use as the first level of documentation. Some apps do not require cell-phone coverage or even internet to capture the data, which then can be stored on the device and shared via the internet at a later date. In the Arctic, where internet access and finding good quality internet connections are a constant struggle, using a simple 3D app is a good option for community engagement through citizen science, capacity building in origin communities, and supporting community-driven self-representation.

3D scanning, again, is a different type of technology that is particularly well-suited for documenting archaeological and hard-surface objects. Scanners can provide excellent quality when calibrated and used correctly, but their cost can be prohibitive. Learning to use scanners also requires some training, but investing in a scanner and a workshop that teaches several community members how to create digital 3D models can foster further interest in using 3D technology locally. The challenge of 3D scanning is twofold. First, scanning, similarly to most 3D technology, develops so quickly that the required hardware, in this case the scanner itself, can become obsolete within a few years. Replacing the unit and re-training local users may be possible but requires financial investment that may or may not be available. Secondly, 3D scanning does not work very well with soft material, many of which are staples of Arctic Indigenous material culture. Skin, gut, feather, fur, sinew, among others, are all difficult to 3D scan and producing a workable digital model by scanning is nearly impossible.

The third method to producing digital 3D models is using a photogrammetry software such as Agisoft PhotoScan (2018) or 3DF Zephyr (2018). These programs use a series of two-dimensional digital photos aligned through a Structure-From-Motion (SFM) algorithm to create the digital structure. Photogrammetry is particularly useful when working with Arctic and Subarctic collections as it can produce clear models of ethnographic and composite pieces that combine soft materials and hard surfaces. On the one hand, photogrammetry also has its drawbacks. For instance, modeling very small items such as beads or needles, elongated items such as atlatls or spears, and shiny items such as ivory or baleen requires a lot of patience and the ability to accept unpredictable results (Csoba DeHass et. al., 2017: 27). On the other hand, photogrammetry does not require specialized hardware and uses only a digital camera at its most basic application. Many origin communities have access to digital cameras and photogrammetry software can be quite affordable. The challenge of using it for an extensive outreach and capacity building stems from the fact that using photogrammetry software and taking photos appropriate for 3D modeling has a sharp learning curve that is difficult to master in a day-long workshop. For this reason, active collaboration in project design is a must when creating 3D models of Indigenous heritage.

Moreover, articulating clear expectations of the level and frequency of 3D modeling training provided to origin community members needs to be a part of all projects using 3D technology.

Finally, the question of ownership, archiving, access, and use-rights of 3D models and their corresponding point clouds are still a murky territory lacking guidelines and regulations. When working with Indigenous material culture, the question of cultural property rights, the rights of the person creating the 3D model, as well as the Principal Investigator (PI) of the project need to be carefully negotiated. Because point clouds carry the information needed to replicate an object, they carry culturally specific information that needs clearly laid-out protection. Sustainable and secure archiving of the digital files is perhaps the greatest challenge for the future of cultural heritage digitization, one that needs collaborative decisions and the flexibility to accommodate the cultural conceptualizations of the digitized items according to the origin and descendant communities. For this reason, archiving, control, access, and future use of point clouds should be negotiated and carefully laid out as part of the collaborative process. For the same reason, archiving in public digital repositories that provide free access to all end-users is not an appropriate option for digital 3D models of Indigenous material heritage. While a community may wish to use 3D technology to digitally document and preserve information about items located in their possession or in museum collections, they may also decide to restrict access to the model in order to comply with culturally specific restrictions. Other communities may decide that the 3D model does not carry the same cultural meaning as their physical counterpart and subsequently make the models available to the greater public. While the theoretical implications of digital 3D models in the preservation of Arctic Indigenous heritage is still unexplored, the usefulness of the technology that can be deployed to produce digital models in communities and in collections alike is manifold. Consequently, digital 3D models contribute to the development of local heritage preservation practices while also provide information that can be shared across the Arctic.

3D Physical Replicas

While the use of digital models for cultural heritage preservation and perpetuation continues to grow at a rapid pace, the addition of 3D physical replicas is emerging as a new domain and adding to the benefits and challenges of the digital. Once a cultural object has been digitized it is possible to use those files to return back to the physical world using 3D printing and/or 3D milling technology. A physical object, even a replica, has the power to convey a level of realness that a digital model cannot. Therefore, there are many contexts in which a physical object may be preferable for educational and even for ceremonial purposes.

The Repatriation Office of the Smithsonian's National Museum of Natural History (NMNH) in the United States has undertaken a number of collaborations with Native American tribes and Alaska Native villages and organizations to employ 3D replication technology for cultural purposes. In some cases, tribes are asking for 3D prints or milled objects to be produced so they can retain a physical copy of a funerary object which they intend to rebury (Hollinger et al., 2013). Having a physical object is preferable to photographs for handling and teaching about past material culture and artistic attributes. Items from shaman's graves around the village of Hoonah, Alaska, which were repatriated as funerary objects by the NMNH, had multiple reasons why the community wanted them to be digitally documented and replicated. In addition to being very fragile, many were painted with mercury based red paint which posed a physical hazard to the handler. However, they also posed a spiritual hazard on that many Tlingit consider shamanic items untouchable because they may possess dangerous spirits. Printed and milled 3D replicas allow the community to handle and study their ancestral objects with much less risk to themselves as well as to the original objects.

Printed objects can be made in a variety of materials with different strengths and colors. Some prints can reproduce the color of paints on objects with great accuracy. They can also reproduce movable parts and complex spaces. In the Hoonah collaboration, the Smithsonian printed rattles with the beads still inside them using ct-scan files. In another collaboration with the Central Council Tlingit and Haida Indian Tribes of Alaska, the NMNH digitized two rare spear throwers (*Shee aan* in Tlingit) and then had them printed in a high strength nylon so the prints could be used to throw actual spears or darts. There had been questions as to whether the *Shee aan* were functional or ritual shamanic objects and the approach demonstrated that the throwers were likely functional hunting weapons. The prints were then taken to a clan conference in Sitka, Alaska, where Tlingit students and clan leaders experienced using them first hand. Printed throwers will now be available for use in Tlingit classrooms and culture camps and carvers can study them to revive their manufacture and use. Although not a true repatriation, it is a form of cultural restoration using 3D technology.

The prints can also be painted by hand, with attachments of hair, leather, shell, etc. applied by traditional methods. In the Hoonah/Smithsonian collaboration, dozens of milled and printed objects will be finished with painting and attachments by a team of Tlingit artists from Hoonah. This approach combines the high tech with the traditional arts and techniques and enhances community engagement and control. The project is producing two sets of the replicas, one for the Hoonah Indian Association to display and use for education in Hoonah and one for the NMNH to retain at the Smithsonian for research and education. Showing that the replica production process is not exclusive to large institutions, some of the objects are being milled in village of Hoonah using milling equipment already in the community. Milling replicas can be done using a range of materials including metal and foam, but being able to mill them from the same material as the originals, as can be done with wooden objects, offers the benefit of more closely matching the originals since they might even smell the same. Working with the Tlingit *Dakl'aweidí* clan, the Smithsonian used a laser scanner and photogrammetry to digitize a clan crest hat in the form of a killer whale, which had been repatriated to the clan years earlier as a sacred object and object of cultural patrimony (Hollinger & Jacobs, 2015). The digital files were archived as a form of security in case anything happened to the original, but the clan leader also authorized the Smithsonian to mill an exact replica for exhibit at the museum. Working in close consultation with the clan at every step, the hat was milled from alder, reproducing even the knife marks from the original, and then inlaid with abalone shell, and painted by hand. The replica hat was danced together with the original by clan members in Sitka and later at the NMNH. Although accessioned and on exhibit at the NMNH, an agreement with the clan allows for the replica to be checked off exhibit to be danced as regalia, but it is not considered a ceremonial crest object because it has not undergone a ceremonial dedication process. The 3D models are also viewable on the Smithsonian's 3D viewer, but the clan leader, to protect their cultural property rights, asked that the models not be easily printable.

Tlingit caretakers of clan crest objects now recognize the potential for 3D digital files to serve as a backup which can be called upon to aid in replacing or repairing their precious ancestral objects

(Hollinger, in press; Hollinger et al., 2013). They now frequently request the Smithsonian's assistance with digitizing their objects and archiving the files. In addition to being used in printing and milling, the 3D models themselves can serve as an aid for traditional carvers who were previously limited to 2D photos when called upon to replace an object. The digital files can also be used to recover exact measurements that can be critical in carving an accurate copy. The NMNH recently entered an MOU with the Tlingit *Kiks.adi* clan to scan and then digitally repair a broken hat in the Smithsonian collection and then use the files to mill a new intact hat to replace the original. Again, although not a true repatriation, this is an example of a cultural restoration that is made possible by the application of 3D digitization and replication technology to repair and remake a cultural object which will be formally brought out in ceremony to fully replace the original.

These examples illustrate the great potential for application of 3D technology in the service of Indigenous communities and caretaker institutions that would have been difficult to imagine just a few years ago. As more communities and caretakers come to understand the capabilities of the technology, we are likely to see a boom in the adoption of these tools to aid in preservation and perpetuation challenges. Objects not subject to repatriation laws, whether because they are in private collections, or because they do not fit a repatriation category, may be replicated using this technology. This option might convince private collectors to return the original if they can retain a 3D replica. Similarly, if deemed appropriate by the community, a replica may be made to replace an object that cannot leave a museum. Items too fragile to be loaned by a museum for exhibition could be digitized and even repaired digitally, and then remade for exhibition.

Conclusions

In our discussion we highlighted key concepts and issues pertaining to the role of 3D technologies in the preservation of Arctic and Subarctic Indigenous heritage. It is important to recognize that we are at the very beginning of understanding how each Indigenous community will use these technologies for their locally driven strategic development. Researchers, museum personnel, and origin community members interpret the significance of 3D technologies from their own perspectives. Yet, the goal of reconnecting Arctic Indigenous communities with their ancestral possessions brings all stakeholders together in their shared task to support community-based development and capacity building. 3D technology has the potential to empower communities and support their own decisions of what should be modeled, preserved, printed, and interpreted as a heritage piece. 3D technology also has the potential to deconstruct the researcher-researched paradigm (Isaac, 2015) and place origin communities in the driver's seat in deciding what can be physically or digitally replicated or removed from their communities.

For these reasons, 3D technology should be part of a comprehensive approach to heritage preservation of both archaeological and ethnographic collections. To support the wide use of 3D technologies, it is necessary to develop best practices that are informed by collaboration and community input from a variety of Indigenous stakeholders across the Arctic. By providing a guide on how to best assist communities in understanding choices available to them through 3D technology, we can also inform policy on the creation and handling of 3D digital models and printed replicas in a way that takes Arctic realities into consideration. It is also necessary to outline the intellectual property and cultural rights regarding 3D points, 3D prints, the manner of creating and processing digital Indigenous heritage material, the way we engage with them as researchers and end-users, and the type of access local communities permit (Magnani et al., in press). Creating culturally responsible collaborative data sharing and curation practices that are developed from local epistemologies will support community well-being through reuniting tangible and intangible aspects of Indigenous heritage. 3D technologies can provide a sustainable heritage preservation network that help better understand cultural connections in Arctic regions while supporting Indigenous rights of self-representation.

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