STANDARDIZATION AND ITS PLACE WITHIN 3D DIGITIZATION OF CULTURAL HERITAGE

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STANDARDIZATION AND ITS PLACE WITHIN 3D DIGITIZATION OF CULTURAL HERITAGE

Sarp Kürkcü
111677002

Assist. Prof. Dr. Dilek Gürsoy
İstanbul Bilgi University

Assoc. Prof. Dr. Esra Yıldız
İstanbul Bilgi University

Assist. Prof. Dr. Utku Kocaman
Mudanya University

Date of Approval: 1/7/2025

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Name Surname: Sarp Kürkcü

Signature:

ABSTRACT

Digitization, which is the action of converting something to a digital form, has been a part of cultural heritage for decades beginning with two dimensional (2D) digitization, as well as digitization of audio recordings. However, three dimensional (3D) digitization itself is considered relatively new. 3D digitization brings different use cases, both for experiencing and protecting the objects within cultural heritage collections. It is possible to archive, preserve, restore, even reconstruct and remix the existing cultural heritage objects and create new contexts and attach new life experiences to them. However, with this many use cases and different techniques to digitize objects, there is not a clearly defined standardization of 3D digitization processes. With the addition of fast moving technological advancements throughout the field, a persistent quality and safeguards seem absent. To clarify the status of standardization, grounded theory has been utilized as the methodological approach. In order to collect data for this approach an online survey was created and sent out to the institutions that agreed to participate. Created hand in hand with the literature analysis and grounded theory, the survey revealed that not one standardization attempt is necessary for all the use cases since every use case has different needs and requirements. The survey also revealed that not every public collection is the one and only version of the digital objects, also the access is not always apparent. This research contributes to the discourse of digital collections, possible future virtual tour techniques, licensing of digital objects and accessing as well as experiencing cultural heritage as a human right.

Keywords: Cultural Heritage; Standardization; 3D Digitization; 3D Scanning; Virtual Tours

ÖZ

Dijitalleştirme, bir nesneyi dijital forma dönüştürme eylemi olarak uzun yıllardır kültürel mirasın bir parçasıdır. Bu süreç, ilk olarak iki boyutlu (2B) dijitalleştirme ve ses kayıtlarının dijitalleştirilmesiyle başlamıştır. Ancak, üç boyutlu (3B) dijitalleştirme nispeten daha yeni bir gelişme olarak kabul edilmektedir. 3B dijitalleştirme, kültürel miras koleksiyonlarındaki nesneler için hem deneyimleme hem de koruma açısından farklı kullanım alanları sunmaktadır. Mevcut kültürel miras nesneleri arşivlenebilir, korunabilir, restore edilebilir ve hatta yeniden yapılandırılabilir. Ayrıca bu nesneler yeniden harmanlanarak yeni bağlamlar oluşturulabilir ve onlara yeni anlamlar kazandırılabilir. Bu kadar çok kullanım alanı ve dijitalleştirme teknikleri olmasına rağmen, 3B dijitalleştirme için açıkça tanımlanmış bir standart bulunmamaktadır. Teknolojinin hızlı ilerlemesi, tutarlı bir kalite ve güvenlik önlemlerinin eksikliğine yol açmaktadır. Standartlaştırma durumunu netleştirmek amacıyla, temellendirilmiş teori bu araştırmanın methodolojik yaklaşımı olarak kullanılmıştır. Bu yaklaşım adına veri toplamak için çevrimiçi bir anket hazırlanmış ve katılmayı kabul eden kurumlara gönderilmiştir. Literatür analizi ve temellendirilmiş teoriyle hazırlanan bu anket, tüm kullanım durumları için tek bir standartlaştırma çabasının gerekli olmadığını ortaya koymuştur çünkü her kullanım durumu farklı ihtiyaç ve gereksinimlere sahiptir. Anket, ayrıca her kamuya açık koleksiyonun dijital nesnelerin tek bir versiyonu olmadığını da göstermiştir. Bunun yanı sıra, dijital koleksiyonlara erişim her zaman açık ya da kolay değildir. Bu araştırma, dijital koleksiyonlar, sanal turlar, dijital nesnelerin lisanslanması ve kültürel mirasa erişim ile deneyimleme konularında tartışmalara katkı sağlamaktadır.

Anahtar Kelimeler: Kültür Mirası; Standardizasyon; 3B Dijitalleştirme; 3B Tarama; Sanal Turlar

I dedicate this thesis to the secular methodologies of science, may they shine upon humanity for eternity.

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LIST OF ABBREVIATIONS

2D:	Two-dimensional
3D:	Three-dimensional
3D-ICONS:	3D Digitization of Icons of European Architectural and Archeological Heritage
CAD:	Computer Aided Design
CC:	Creative Commons
CH:	Cultural Heritage
CNC:	Computer Numerical Control
CRM:	Conceptual Reference Model
DCH:	Digital Cultural Heritage
EDM:	Europeana Data Model
FRBROO	Functional Requirements for Bibliographic Records object-oriented
GDH:	Global Digital Heritage
ICCROM	International Centre for the Study of the Preservation and Restoration of Cultural Property
ICOM:	International Council of Museums
ICOMOS:	International Council on Monuments and Sites
IDA	Institute of Digital Archeology
IR:	Infrared
LiDAR:	Light Detection and Ranging
MatCap:	Material Captures
NGO:	Non-governmental Organization
RGB:	Red Green Blue
UNESCO:	The United Nations Educational, Scientific and Cultural Organization
WIPO:	World Intellectual Property Organization

INTRODUCTION

With the invention of photography, museology had to meet a new way of presenting cultural heritage to the masses. In the 1850s, beginning with the South Kensington Museum, which is known today as the Victoria and Albert Museum in the UK, the museums included physical objects as well as photographs of different artifacts from all around the world as a part of their collection. Taking photographs of cultural heritage objects or archeological sites is unarguably not digitization. And yet, encapsulating the perspective of an object and using it in the museology of the 19th century opened up different exhibition methods. The place of photographs, surrogates, copies regarding cultural heritage have met with both praise and negativity, as well an ongoing debate in the subject. Digitization itself is built upon this debate as well, beginning with two-dimensional (2D) and later on three-dimensional (3D) techniques.

Photographs paved the way for preserving and archiving cultural heritage in a whole different way. While being used as an archival method, photographs also accompany objects with better context, whether about the location where they were found or about pertinent objects that are a thousand kilometers away in other museums. Early photographs, in their analog capture form, were delicate and had a great chance of deterioration, so even as a viable technique in itself, it needed improvement. Historically, digitization began as an incremental and difficult process in the 1960s. It was costly and slow due to technical limitations. With every new technological advancement it got better, and humanity went from storing a photograph in a room-size computer memory to carrying thousands of photographs in their pocket on a smartphone.

Cloning or reproducing cultural heritage objects themselves has a similar journey because of its parallel technological advancements. Humanity began capturing a stationary perspective on a special glass, and in the 1850s, museums could present real objects as well as photographs of other collections. Indeed, there were other reproducing methods, such as plaster casts, but even with the relatively lengthy process of taking a photograph

in the early days, it was incredibly faster than casting original objects. And yet, it was just a couple of still images of a three-dimensional object. Filling massive visual gaps regarding the cultural heritage objects were left to the imagination.

The technology improved around the inner workings of photography, including higher quality image capturing techniques or better storing options and yet the clone or reproduction itself was still a 2D copy of the actual object. With the increased accessibility of 3D laser scanners, a new possibility emerged. Instead of capturing just a few angles of objects or even archeological sites, experts in the field could generate wholesome 3D models with the right equipment. It became within reach to capture the entirety of an object in the digital world.

Up until 3D scanning, digitization of cultural heritage had two main usage scenarios: archiving and accessibility purposes. Contextual details of a real-life object, like the dig site or the process of the discovery, could be captured and then either showcased and/or archived for future usage. Scanning delicate objects like paintings and war journals to store or further investigate has also been a viable use case. A similar importance exists in accessibility purposes, because digital files can be accessed anywhere in the world, granted the proper permissions and internet infrastructure. Traveling between cities, or even continents is not necessary when a document needs to be examined. In addition with the emergence of digital art collections across the globe, it is possible to examine pieces through web browsers. These are strong use cases for 2D digitized objects across the globe.

With the 3D scanning and gathering of digital models of real objects, it is now possible to add two additional use cases to this set; recreating the objects[1] through numerous manufacturing techniques and also experiencing them in detail in virtual environments.

[1] The term recreation is being used as an object being manufactured via automated techniques like CNC milling or additive manufacturing. A 2D digitized object is, in the end a 2D digital file that captures to one perspective of an object, therefore cannot be used for recreation. On the other hand, 3D digitization may very well be a blueprint for automated systems.

Indeed, all the previous purposes apply to the 3D models as well, with a little nuance. Just like the invention of photography, 3D scanning had, and still has, its own curve of technological advancement. It is a relatively new imaging technology, and with every incremental upgrade of the hardware as well as software, we are faced with the obsolescence of the previous digital collection for archival and preservative purposes. In the beginning, getting a 2mm detail may be the pinnacle of the technological standard, but a couple of years later, 0.5mm detail capture—four times more detail than the previous example—may be frowned upon.

Along with the speed of technological advancement, there is also the issue of institutions creating their own collections. What are their concerns and purposes for their collections moving forward? Is there a standardization among 3D capturing techniques that ensures the longevity of the collections? This research aims to explore the technical capacity and available approaches to capturing 3D models, as well as understanding how the institutions manage, protect and share their 3D digitized collections with the definitions of digitization, cultural heritage, and standardization.

1.1. Research Questions

These questions create the basis of this research, as well as the origin point of case research:

- Are there common 3D digitization practices used by art and cultural institutions to overcome technical, methodological and organizational challenges?
- Based on ongoing 3D digitization practices around the world, is there a place for standardization in any steps of the process and if there is how these protocols impact the efficiency and sustainability of the processes?
- What impact rapid advances in 3D digitization technologies have on the long-term accessibility of digital cultural heritage?

1.2. Methodology

The research is split into two structures. It relies on literature analysis and following that uses the knowledge gathered to create an anonymous survey. The survey is not person-specific but rather more institution and position-specific. The questions are related to the 3D digitization processes within the institutions, and since most of the precise information may be private, the general approach is to refrain from institution-specific points while getting the answers.

The first chapter of this thesis will create a baseline for the different steps and approaches within 3D digitization. Since the digitization itself is both technical and cultural (in an intangible way, *personal*), to create the questions and interpret the answers scientifically, digitization has to be defined accordingly. The definitions regarding the digitization also include the steps being taken when the process is being used.

The second chapter will focus on understanding how different institutions around the world approach both the procedure and the 3D digitization itself. In order to do that, following the research questions, a detailed questionnaire will be used to get anonymous data. The questions are related to institutions, and they are not about the people but the processes and digital collections. The only requirement is that the person answering the questions must be a part of the digitization process and, therefore, competent enough to answer accordingly. Since there are no clear-cut positions for the digitization process between institutions, the questionnaire is being sent to more generic email addresses, asking politely to be forwarded to the specific department and/or person. There have been website observations as well since some digital collections are, at least in one form or the other, open to the public and can be interpreted according to the literature analysis. Some tools, which the collections are part of, give enough information about the origin or the techniques of the processes.

As for the limitations, the language barrier excludes some parts of the world since not every institution can or wants to communicate in English. Also, some institutions may not want to give any kind of information regarding the acquisition of their 3D digital

collections. In addition to these, when requesting help from a more generalized email address, it is not possible to measure the participant's knowledge regarding the digitization process.

DIGITIZATION OF CULTURAL HERITAGE

2.1. Definitions

2.1.1. Cultural Heritage

According to the The United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Convention, Cultural Heritage (CH) is defined as:

> […]architectural works, works of monumental sculpture and painting, elements or structures of an archaeological nature, inscriptions, cave dwellings and combinations of features, which are of outstanding universal value from the point of view of history, art or science; […] works of man or the combined works of nature and man, and areas including archaeological sites which are of outstanding universal value from the historical, aesthetic, ethnological or anthropological point of view (UNESCO, 1972, p. 2).

The value may be of universal importance, but over time, local, national, and regional importance has been accepted into the definition (Sotirova et al., 2012). These values, the scope, and the area of contribution are not always constant. A value that was considered local at the time may very well be global in the future. So the definition is always changing and somewhat inclusive, therefore having a hereditary merit.

Aside from the inclusion of intangible cultural heritage, in 2003, UNESCO also defined Digital Cultural Heritage (DCH). According to the official charter, DCH includes both digital data that was converted from analog sources and objects that were born digital, meaning there is no other form or format that the object has (UNESCO, 2003b). This differentiation creates a discussion on its own. On one hand, it is claimed that a copy of the original object may shift the context and relevance of the original object (Younan & Treadaway, 2015). On the other hand, some claim that with every new copy, the importance of the original object is heightened (Walsh, 2007). This discussion, when it is grounded on the connection between the physical and the digital object, is relevant, but according to the definition of UNESCO's Charter on the Preservation of the Digital

Heritage, a digital object becomes a CH object itself. When the connection is severed, there is no apparent reason to compare a digital object to the original anymore.

2.1.2. Digitization

The term digitization was first used in 1954, according to the Merriam-Webster Dictionary (Merriam-Webster, n.d.). In its simplest use, the term is broad and includes every attempt at converting something to digital form. However, currently, digitization is used to define attempts at converting analog sources to digital form with various electronic devices and tools. These sources are textual documents, audiotape records, photographs, and CH artifacts—both created by humans and naturally occurring[2]. The tools include cameras, scanners, audio recording devices, and various techniques of multi-dimensional scanners. In its current scope, digitization also encapsulates the processing, storing, and transmission of the data itself (Sotirova et al., 2012). That means the long-term preservation of DCH, as well as access to legally stored digital objects, are within the definition (UNESCO, 2003b).

The digitization process varies between objects since a different, built-for-purpose technique must be used to digitize an audio tape record or a photograph according to their specific nature. Even in the same category, like 3D digitization of objects, different sizes, shapes, and material properties require different techniques (Pavlidis et al., 2007). This variation inevitably brings cost and expertise into the digitization process. Since the hardware and the accompanying software are tailored to the needs of the process, they are considered specialized for the use case. However, this is not a constant; technology in the field is rapidly moving forward, and new techniques or use cases will undoubtedly emerge over time.

[2] An unusual example is the city of Pompeii, which is unique in its preservation via the volcanic eruption. Digitization of Pompeii is a defining example of this phenomenon (Silver, 2016).

2.1.3. Standardization

Standardization in the CH context is regarded as different institutions having a consensus on a standard approach to processing data (Ioannides & Hadzilacos, 2003). Whether it is about the preservation of an oil painting or a limestone statue, a preferred and agreed-upon approach qualifies as standardization, albeit without any clear definition.

The value of standardization is most apparent when it is not there. Humans usually don't perceive the existence of standards and their effect on life until the overall quality of a given aspect of life degrades (Ioannides & Hadzilacos, 2003). The same is also valid for the standardization of CH. Due to technological advancements, there is a boom in cultural heritage-related data gathering and storage. This pace regrettably raises questions about the quality of the aforementioned gathered data (Quintero & Eppich, 2016). These questions help define the parameters of, or the absence of, standardization in relevant subjects. The same technological advancement also affects the sustainability of the standardization attempt. Current technologies usually surpass the written guidelines (Terras, 2015) and this creates the question of whether a standardization is even possible within CH.

Standardization itself is not a sole definition but a supplement and adjective to CH-related subjects. Including digitization, preservation, access to DCH objects, and restoration. There may be ties and relations between different steps of 3D digitization, which may affect the standardization since then there won’t be a singular reason for a standard procedure.

2.2. Historical Context

3D digitization is often compared to photography when it comes to its impact on CH (Scopigno et al., 2011). There are two distinctive sides to this comparison, whereas one is historical and the other is technical.

2.2.1. Photography and CH

Historically, the introduction of photographs to museum culture has been somewhat controversial. When photography waded into museums as early as the 1850s, it was not welcomed into the fine arts exhibitions. Instead, it was part of the *Industry Pavilion of the Exposition Universelle* in Paris in 1855 (Walsh, 2007). One of the first examples of a post-photographic museum that not only accepted but thrived with the use of photography was the South Kensington Museum, today known as the Victoria and Albert Museum. Located in London, United Kingdom. This museum had one distinctive goal for its existence: To improve the taste of both the British industrialists and common folk with the influence of great art (Walsh, 2007). This purpose, admittedly, eliminates the singular idea of collecting everything in its pure and original form. Therefore, Henry Cole, who was the first superintendent of the museum, used photography to expand the collection of the museum, as well as the context behind the existing one.

London's *Crystal Palace Exposition* in 1851 also helped create this expansive ideology, Peter Walsh defines the exposition as "the prototype of the world's fair approach of representing all the cultures and industries of the globe in one place and making them into popular entertainment" (Walsh, 2007, p. 24). It had a vast collection of technological advancements that came from around the world, and the city had a predisposition towards new technology.

Without the context of museology, the use of photography may seem revolutionary and linear—copying an existing object without acquiring it. And yet, the idea of copying an object onto something else (albeit clay, canvas, glass, etc.) was not new at the time. Plaster casts, handmade engravings, reproducing paintings, and creating sketches of CH objects were all existing and applied techniques. However, photography, as Susan Sontag said, "is never less than the registering of an emanation—a material vestige of its subject in a way that no painting can be" (Sontag, 1977). It is the exact replication of the object in a seen light because it is the same light that bounces back from the object to the photograph.

It is also imperative to consider photography in the museum and CH context as not just a still image but a series of technological approaches. Zoetropes, which use either paintings or a series of photographs to make the objects seem to be in action, have a place in museums as an exhibition technique (Jardine, 2019). Stereo pairs of photographs were also used to emulate 3D images that have been around since the 1850s. The technique was used to showcase the CH objects in Egypt, from stationary sites like the Great Pyramids and the Sphinx to smaller and somewhat portable artifacts (Silver, 2016). Lastly, a technique that was invented by François Willème around the 1860s is of utmost importance. His system, which is called *photo sculpture*, consists of capturing the subject with 24 different cameras and then using a magic lantern (an early system of a projector) to transfer it onto clay via a pantograph (Moulden, 2009). Capturing the subject in 15-degree intervals, a contour was somewhat easy to capture. The magic lantern helped the photographs get bigger; therefore, scaling was also a possibility. It is claimed that the customer had a range of selections from the size of a medallion to a full-size bust (Mayor, 2023).

The importance of photo sculpture is not just in the usage of photography or combining technological advancement with art and CH. It is also a solid bridge between photography and 3D digitization techniques and an apparent example of their similar historical course. A valid and frequently used 3D laser scanning technique called *shape from silhouette* is exactly based on the photo sculpture that was from the 1860s (Pavlidis et al., 2007). There are indeed advancements and added steps in approach, but the basis of the technique remains roughly the same.

Another common point in the historical course is that neither 3D digitization nor photography was specifically invented for CH necessities. Creating 3D digital models was initially developed for industrial applications, including manufacturing and rapid prototyping, but was then included in the arsenal of CH experts (Agosto & Bornaz, 2017). The same can be said for photography, which was initially categorized as an industrial application and regarded as an automated drawing system (Walsh, 2007).

Their reception from both experts and people in general has similarities too. Contrary to the myth, photography did not struggle for decades and then finally got accepted by the masses. Instead; based on time, location, and contextual culture, the fame of photography has risen and fallen (Walsh, 2007). 3D digitization, which began its life in the late 1990s, has had a similar journey up until now.

2.2.2. 3D Digitization of Cultural Heritage

3D digitization of CH is strongly tied to the technology that enables it and to the experts who are eager to implement these techniques. The technical aspect is tied to both hardware advancements, such as developments in digital photography equipment, and software advancements, such as the automatization of algorithms (Malik et al., 2021). Historically, the first use of 3D digitization of objects dates back to 1997 by the Institute for Information Technology at the National Research Council Canada (Guidi & Frischer, 2020). On the other hand, the first big press coverage was done with the *Stanford Digital Michelangelo Project*. After that, with ample technological progress, 3D digitization has been embraced by the CH institutions.

In terms of technology, there have been two important milestones in the embrace of 3D digitization. One was the laser scanning technique. The other was the Structure from Motion (SfM) systems, basically known as Photogrammetry[3] (Agosto & Bornaz, 2017). Based on these two advancements and the other incremental steps, there have been substantial experiments within the CH institutions, including European project 3DICONS, Smithsonian 3D digitization and UCL-s Petrie Museum of Egyptian Archaeology in the 2010s (Malik et al., 2021).

[3] Photogrammetry, to be explained more in detail further, is a technique of 3D model creation which relies on multiple photographs taken from different angles (hence, the *motion*) and an algorithm that can connect these photographs together.

On the experts and expertise side, UNESCO, ICOMOS (International Council on Monuments and Sites), ICOM (International Council of Museums) and some other NGOs try to create healthy communication between the industry and CH institutions. Beginning in 2011, ICOM and WIPO (World Intellectual Property Organization) have been working hand in hand about the access to and dissemination of digitized cultural artifacts (Sotirova et al., 2012). UNESCO and ICOMOS also try to convey industrial know-how to CH institutions and individuals through workshops and training around the world. Especially in situations where there are at-risk cultural heritage sites because of the regional conflict (UNESCO, 2016, 2018).

Although historically new, 3D digitization has been an integral part of CH institutions. Due to its early state, there are rapid developments that may endanger the past or current projects therefore this research aims to create a baseline from all the information that it has gathered.

2.3. The Process Of 3D Digitization

3D digitization is considered to be a multidimensional process (Pavlidis et al., 2007). It involves capturing the data, storing and preserving it, and providing ample infrastructure to give people access to it. This plethora of responsibilities creates the main structure of 3D digitization. These steps, usually in written order, are part of collection management (Horan, 2013).

2.3.1. Capturing the Data

Capturing the data is the first step in the digitization process for CH artifacts, whether relatively small objects or monuments (Pavlidis et al., 2007). Technically, there are two main ways of capturing the data: Image-based and range-based modeling (Silver, 2016). Image-based systems use photography and their relative location (usually topographic data analyzed from the image) to stitch a 3D model. It is both used for objects and monuments. Their unique advantage is that they are able to capture texture detail (Pavlidis

et al., 2007). In these methods, there must be a system that interpolates digital images in order to create high-resolution, scaled 3D models (Themistocleous et al., 2015). GIS (Geographic Information Systems) which is another branch of image-based modeling, also has a use for archeological mapping and management (Silver, 2016). Image-based systems, also commonly known as Photogrammetry, relies on both the photographs and the algorithms that stitch them through analysis. Both the number of photographs taken from various angles and the algorithm that calculates the distance based on these photographs affect the accuracy of the object immensely.

Range-based systems usually consist of a laser scanner that projects the beam and measures the point accordingly, as well as recording the position of that particular data. The prime advantage is that the points are more accurate than image-based systems. Texture data is, unfortunately, not available in this method. After the scanning of all the points, usually referred to as a point cloud (Figure 2.1), is done, there must be a mesh modeling procedure that calculates the distance between the points (Li et al., 2010). Laser scanners can be stationary or mobile; they can be on the ground or in the air. They can also reveal details that are invisible to the naked eye, providing valuable data to capture (Silver, 2016).

Figure 2.1. A Point Cloud Example of a Statue



(Source: *Kürkcü, S. (2024), an example of a point cloud structure on left, which is the basis for the mesh model on the right. Data gathered from the approximation between the points creates the mesh model via computer algorithms.*)

Image and range-based scanning techniques can also be used together, albeit creating different data sets. But these data sets can be combined together to create a 3D model which has the accuracy of a range-based scan and also a texture to be covered onto. These two camera systems have their lens distance measured and calibrated, so their difference in parallax can be compensated through stitching procedure using the inherit data from the device itself. Most relatively inexpensive (sub-1200 EUR mark) commercial 3D object scanners of the 2020s including Revopoint, Einstar and also iPhone Pro and iPad Pro lineups, beginning with iPhone 12, have this kind of approach.

Revopoint, in their POP series 3D scanners, use Dual-camera Infrared Structured Light which consists of an IR camera, as well as an RGB camera. IR camera captures the point cloud data, while RGB camera envelopes it with the photographic texture (Revopoint, 2023). Einstar also uses a similar technology, both a IR and an RGB camera to capture details of an object (SHINING 3D, 2023).

iPhone Pro and iPad Pro lineups, on the other hand, use a different kind of light source to capture the point cloud data of 3D objects. Beginning with the iPad Pro 2020 (11-inch and 12.9-inch models) some Apple devices began incorporating LiDAR sensors within them (Kuçak, 2023). The main purpose of these sensors was to increase the low light photography capacity of devices by increasing the autofocus capabilities.

Since its debut, LiDAR sensors can be used in numerous applications. *Measure*, a native Apple app, can use the LiDAR sensor to calculate real world distances more accurately. Apps like *Floorplan* can create plans for further use cases. Also with mobile apps like *PolyCam* or *Scaniverse*, 3D digitization is possible.

All these devices contain multiple fixed distance cameras, calibrated from the get go and unchangeable by the user. Their RGB and specialized cameras can compensate for their position differences through software.

2.3.2. Storing and Preserving

The data that was captured has to be stored in a viable and efficient way. There are different concepts under storing, like *protection*, *preservation*, and *conservation*. Although these terms are being used interchangeably, there are distinctions between them. These definitions also differ in meaning between tangible and digital CH.

Protection is defined as prevention from harm and, in CH terminology, it is usually used in parallel with *preservation* (Silver, 2016). *Preservation*, on the other hand, also includes legal bindings and legislative actions.

When it comes to *conservation*, the definition branches out into three categories. *Preventive conservation*, which includes preservation and therefore, protection, aims to slow down degradation and aging. *Remedial conservation* aims to help the subject tend itself to its principal state. *Restoration* is the act of moving the subject forward to its targeted appreciation and use (Silver, 2016).

Regarding tangible CH, these subjects are well-defined and descriptive, but in the digital CH scene, some of these concepts morph into new notions. *Preservation* has to be able to ensure the physical sustainability of collected data. Since digital media is easily corrupted and prone to be destroyed in a catastrophic incident, preservation has to deal with it (Sotirova et al., 2012). Physical servers or cloud systems have solutions for that problem, but a standardized solution is not yet apparent (Quintero & Eppich, 2016). Another preservation issue is *Digital Obsolescence*. Also known as data extinction, it is the problem of having unreadable data even with intact media (Belhi et al., 2017). In physical obsolescence, the data storage is intact and working, but there are no viable hardware methods to connect it to the system. Decline in the availability of optical drives on notebooks is an apparent example because, without optical drives, it is impossible to read the data from disks like CDs or DVDs. Another conundrum is the software obsolescence, which includes the old and unreadable file formats. Some old CAD (Computer Aided Design) file formats like GEM or IBM CAD are unreadable with current programs (Belhi et al., 2017). This issue arises sometimes with the obsolescence of programs that read the file formats, in other times with the discontinued support of operating systems for these programs due to technical advancements (Sotirova et al., 2012).

A crucial part of storing digital objects is the idea of metadata. Metadata, which is defined as "data, describing the data" is a plethora of descriptive attributes that points to and makes the 3D model easier to find in the database (Guidi & Frischer, 2020). Of course, the idea of metadata is not solely in the field of CH. It can be found in any kind of archival database, whether it is a library or a hospital. But as like any other database with a vast number of items in it, CH departments are in need of a functional and agreed upon metadata structure. There are different types of metadata; some are descriptive like the title, author, and subjects. Some are technical, including file formats, scanning dates, and resolution. Some are for legal purposes like ownership, copyright, and licenses (Sotirova et al., 2012).

Unlike any other categorization system, metadata of CH objects has a vast number of identifiable parameters. As an example, CIDOC-CRM (Conceptual Reference Model) which is a theoretical and practical referencing model that is being used across museums

and CH institutions, has Class and Property hierarchies waved together. Model version 7.2.4, which was released February 2024, has 81 Classes and 160 Properties. The system is poli-hierarchical, but through top-down expansion and a proper order a mono-hierarchical presentation is possible (CIDOC CRM Special Interest Group, 2024). Systems like CIDOC are being used for the whole organization and not just for digitized CH objects. But with its first object oriented version (4.0) from 2004, and its declaration of official standardization as ISO 21127:2006, it is constantly evolving to meet the needs of current experts and institutions (Sotirova et al., 2012). CIDOC is not the only metadata system currently in use and with the inclusion of FRBROO (Functional Requirements for Bibliographic Records object-oriented), EDM (Europeana Data Model), VRA Core any organization may choose any (or all) of these systems to catalog their DCH collection.

2.3.3. Access

Every object with cultural significance, whether digital or physical, that is in the possession of archival institutions, are considered “collections”. Collections are of utmost importance to these institutions, because the existence of collections are one of the foundational pillars of these institutions. Without the collections, museums are unable to perform some of their fundamental purposes through preservation, research, exhibition and interpretation (Horan, 2013). In order for institutions to fulfill their purposes, they need to create a proper way of access to the collections. And for physical objects, there have been tried and true ways, a similar approach needs to be established for digital collections too. The importance of access relies on this fundamental existential pillar.

Yet, the access to digital copies freely and openly is still considered a threat to museum culture. One reason is, it is believed that simulations could diminish the impact of authentic artifacts, by overexposing it via copies (Younan & Treadaway, 2015). This discussion originates from a 1935 essay titled *The Work of Art in the Age of Mechanical Reproduction* by Walter Benjamin, therefore even before 3D digitization, due to copying and duplication of CH artifacts with numerous techniques, it has been thoroughly examined (Walsh, 2007).

Economics is also another factor for these reasons. Especially in Europe and the United States, with the reduction of state funding, museums are usually believed to sustain themselves through admission and physical attendance (Elias, 2019). Even during the late 20th century, museums were anxious to see their attendance numbers drop due to technological advancements (Horan, 2013) since 3D digitization is, if needs to be done thoroughly, a costly endeavor and some institutions are reluctant to share their own collections with the public. For some institutions, if and when the access to this kind of 3D data is granted, it comes with copyright and restrictive agreements (Elias, 2019). The cost of digitization and maintaining access to these collections is nevertheless a budgetary item and a proper funding is required. The sustainability of both the institutions and digitized collections are highly related to these economical balance scales and access is a crucial part of it.

As the owner and provider of collections, institutions decide how much of their collections are accessible. And yet, access to cultural heritage itself is strongly tied to human rights. Experiencing cultural heritage through physical objects or customs and linguistic practices is a right and should be protected regardless (Blake, 2015). This notion also encompasses DCH as well, because by UNESCO it is defined as a part of CH (UNESCO, 2003b).

This, admittedly creates an imbalance between the institutions, which have the collections in their possession and the people, who inherently have a right to access to these collections. When it comes to physical attendance to the museum grounds, there is usually an admission fee that must be paid. The price is varied, depending on the credentials of the visitor, like a student or a child. There is a valid precedence for the accessibility of CH objects, and yet there are no clear standards or even categorizations for digital access.

2.4. Use Cases of Digital Cultural Heritage

Different digitization techniques create different types of models that are strong in specific attributes and this is admittedly one of the strong suits of having multiple

digitization options when needed. This variety also creates a conundrum, when the models need to be put in use and have case-based needs. If the measurement accuracy is a prime concern and color data is secondary, that 3D model may not be suitable for digital display. A high-accuracy model of a monument can be captured, but every little bit of data requires a portion of computational power, therefore the accompanying computer to the process may be unfeasible.

The strength of specialized digitization methods also comes with the confusion and mispurposed cases. Not all digitized models are cross-usable between different cases. Without a clear definition of standardization, whether due to accessibility through cheaper or commercial solutions or the rapid advancement of technology, makes it harder for institutions to choose the right method for their needs. In order to know how to digitize a CH object, first, it is imperative to decide how it is going to be used. It may be for just one use case, or there may be multiple places for the object to appear. After the clarity of purpose, comes the appropriate solutions to digitize, store, attach metadata, and grant access to. Digitalization, the end product which is "digital", is not just a tool. As defined by Ross Parrt and Vince Dziekan, "It is also a process, strategy, vision […] which the museum finds itself today in its contemporary circumstance; it is a cultural condition […]" (Parry & Dziekan, 2021).

The absence of standardization has a plausible explanation since none of the two institutions are the same, nor their use cases are identical. So the use cases, although may seem like clearly defined departments in themselves, may vary between different institutions. With all this ambiguity, every institution has to navigate on its own between different techniques and use cases. And the absence of standardization is a crucial part of this entanglement.

2.4.1. Archiving

Archiving is the historical acceptance point of digitization within museums (Bounia, 2023). Digitization, as a whole, has a relatively longer history beginning in the 1970s,

including 2D digitization of paintings, postcards, letters, and diaries; as well as digitized tape recordings, interviews, concerts, music albums had a colossal impact on archiving (Horan, 2013). 3D digitization of CH, however, has a shorter lifespan, dating only back to the late 1990s (Agosto & Bornaz, 2017).

One of the crucial parts of archiving is, it is the baseline of all other use cases. Every digital object has to be stored somewhere with the appropriate information attached to it. The type and quantity of information, the quality and accuracy of the 3D model, these specifications are not standardized, because technology is rapidly changing and requirements of the objects are also evolving based on the use cases (Bachi et al., 2014). Technological advancements are indeed welcomed, because it opens up the more economical and accessible digitization possibilities (Elias, 2019). The same advancements also create numerous debates over the viability and value of digitizing procedures. Uncertainties about the technical aspects like the metadata, quality and file format of the models create organizational problems for the institutions (Bounia, 2023).

Archiving aims to ensure the longevity of the data that was gathered. This includes taking precautions against digital, as well as physical obsolescence. When considering museums and archival institutions, as long as physical pieces are preserved and thoroughly maintained, there are and will be multiple chances of digitization if needed. The same cannot be noted for the monuments, historical sites, and statues that are in danger due to wars and conflicts.

There have been numerous monuments from both Syria and Iraq that were partially damaged or completely destroyed because of the regional conflicts (Wahbeh & Nebiker, 2017). Different attempts have been made to digitize monuments like The Minaret of the Umayyad Mosque in Aleppo, Baalshamin Temple and Arch of Triumph both in Palmyra, but since the region is politically volatile, instead of carrying professional equipment and crew to the scene, most approaches include tourist photographs, as well as guerilla-like captures of the monuments in question (Khunti, 2018). Including its destruction in 2015, the Arch of Triumph of Palmyra is a prime example of how a lack of standardization may

affect the archiving, and through the archived digital object, the whole reproduction process.

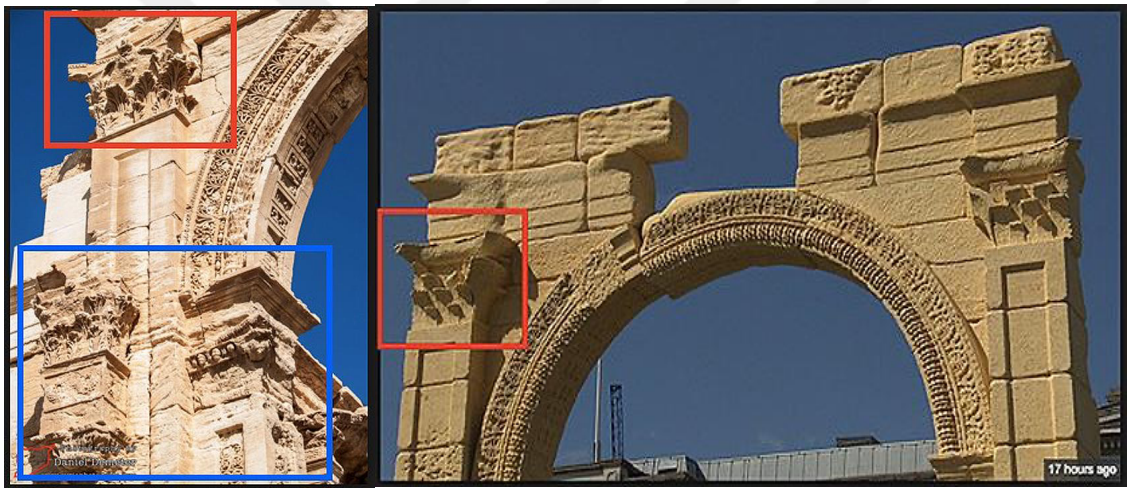
There are several efforts to capture the 3D model of the Arch. Although all of them use photogrammetry as a tool, some incorporate different techniques to improve the outcome of the digitized archival object. The most notable and controversial 3D model is from the Institute of Digital Archeology (IDA), which mostly consists of images collected from tourists and also used to replicate the arch in different cities as an exhibition (Khunti, 2018). Other approaches, which combine photogrammetry with 3D modeling techniques to improve the accuracy and detail level, are a possibility as well. As an example, Panoramic image-based modeling, which includes aligning the source photographs of the monument to wrap around and then creating surfaces and primitives to manually add details to the 3D model file, is a tool in itself (Wahbeh & Nebiker, 2017). Unfortunately, due to their nature of not being standardized by the capture device, pixel count, or dimensional ratio, a person has to align them manually and inspect the details hidden to the algorithms. This means there is no automated procedure to flesh out the intricate details of the monument and a 3D modeler has to digitally carve the details manually from the reference photographs. This is a tiresome and time-consuming process, depending on the complexity and the appropriate skill, but it doesn't change the fact that modeling is manual labor.

It is argued that, in order for an archival 3D model to work, it needs to get as much detail as possible. In favor of this notion, for the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) and its members, authenticity is a crucial part of the preservation of monuments and sites (Khunti, 2018). It is even arguable that inaccurate reconstructions, which are being built by inaccurate 3D digitized models, can mislead the public and professionals about the monument or site itself. This is also considered an ethical problem by the ICOMOS because authenticity and integrity are important as they are integral parts of the preservation.

The 3D model of the arch created by IDA has this specific authenticity problem, which is laid out openly and anecdotally by the Factum Foundation, an organization that is a

partner in the 3D digitization of CH industry. In their blog post, Factum Foundation lays out the details that are present on the arch with detailed photos and also the absence of them through photographs (Figure 2.2.) from the reconstructed arch (Factum Foundation, 2016a). Factum Foundation not only emphasized on the intricate details of the arc itself but also the morphing perception of the public via IDA representatives like Roger Michel and politicians like Boris Johnson, who was the prime minister of the United Kingdom at the time the arch replica was unveiled in London.

Figure 2.2. Arch of Palmyra Details by Factum Foundation



(Source: *(Factum Foundation, 2016), showing the differences between the Arch of Palmyra and the reproduced object that was exhibited in Trafalgar Square*.)

When considering archiving, a lack of standardization about the bare minimum details may be a problem. As said by Factum Foundation in a different statement, considering the Arch of Palmyra, “any recording is better than none” (Factum Foundation, 2016b), but the usability of that recording must be in alignment with the detail it contains, and standardization can play a crucial role there.

2.4.2. Documentation and Restoration

Around the world, CH objects that are exposed to environmental influences, are constantly in danger. Even with sophisticated preservation mechanisms, there are disastrous events that may destroy or damage the objects irredeemably (Santos et al., 2017). Documenting the state of a CH object is possible with 3D digitization, and it may include versions. Instead of archiving an object with its singular condition, documenting may include images, text and context to give detail about the current state. It may be repeated over time, revealing the differences between versions.

Restoration has been an integral part of CH and its importance cannot be overstated. Digitization, mostly in its 2D form, has also been a part of this process. And yet through 3D digitization, there has been an era of trial and error for the perfect approach. For a physical restoration, there are practically a few chances to do it and if the aforementioned object has a delicate structure, this process may create more harm than good. But through virtual restoration, every part can be reoriented in the virtual space repeatedly and after the perfect alignment is established, the work on the real object can begin. A practical example to this is the *Madonna of Pietranico*, a 15th-century painted terracotta artifact from the L'Aquila Museum in Italy. After being destroyed and split into more than 19 pieces in different shapes and sizes, the statue was digitized in 3D and reassembled virtually beforehand (Scopigno et al., 2011). Restoring an object is a delicate process and involves several tests to reattach adjoining pieces. 3D digitization, also with the help of algorithms and machine learning abilities, can also automate and suggest possible orientations for the pieces. Although 3D digitization is not just about automating everything, that aspect is also an improvement in the workflow.

3D digitization, sometimes through unexpected events, has an invaluable position to help in restoration of CH monuments. In 2019, a devastating fire destroyed parts of the Notre-Dame Cathedral in Paris and damaged both the interior and the exterior of the building. Notre-Dame is considered one of the well-documented buildings in the world, in terms of material and construction process since it started being built in the 12th century (Hanussek, 2024). With the help of 3D digitization projects of the monument prior to the

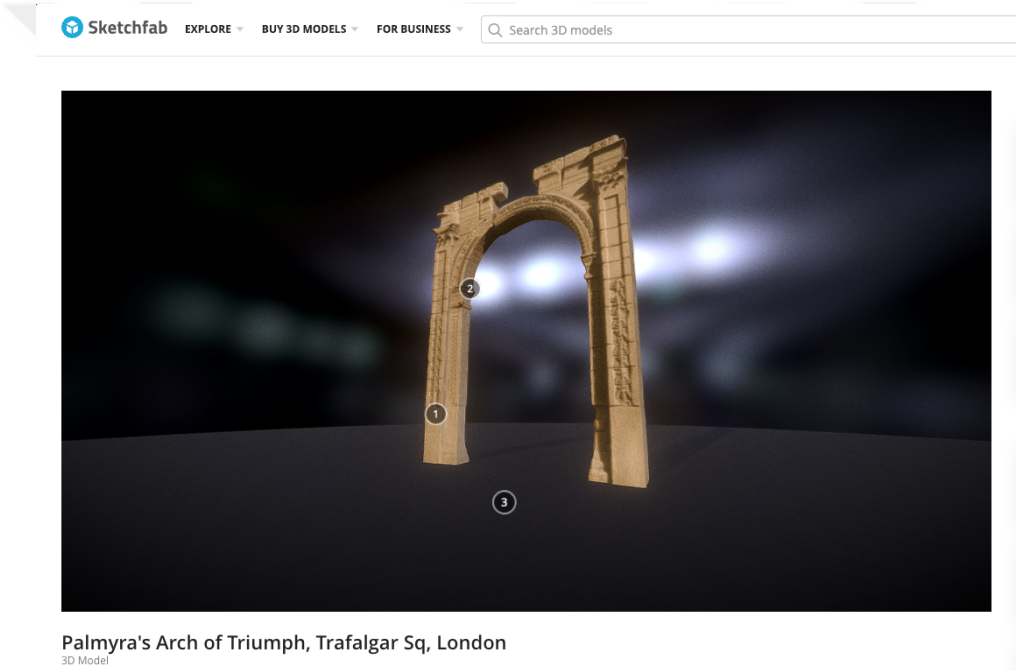
fire, researchers have invaluable information about the roof and the spire of the structure (Quintero, 2020). There have been two different digitization approaches for Notre-Dame, one from the late Andrew Tallon, who used laser technology and advanced imaging techniques to digitize the cathedral (Hertz, 2019). The other digitization effort comes from Prof. Dr. Stephan Albrecht, who is a part of Institute of Archaeology, Heritage and Sciences and Art History (IADK) as a part of University of Bamberg. His team also uses a combination of different digitization techniques to document cathedrals' state in different timeframes, the most recent one being relatively close to the fire (Weismayer, 2020). Both of these models are considered accurate enough to help experts along their way of restoring the building. Accuracy and extensive documentation are strong points for these digitized projects.

Unfortunately, not every monument has a steady documentation process like Notre-Dame. The Arch of Palmyra in Syria is a poor example of it. Acquired 3D model of the arc by the IDA had its problems as an archive, and the problems multiplied when the replica of the arch was built. First of all, it wasn't built in its original scale. It is smaller, approximately around two-thirds of the original monument and this has no significant advantage (Khunti, 2018). It was also made by different materials and the production technique is mostly CNC, which was of course not possible at the time the Arch of Palmyra was built. Neither the details nor the size and scale of the monument itself is up to the original. If it is considered as a warning for how fragile the heritage itself in the face of human destruction, it may be considered a valid statement but the replica of the arc is meant to be taken to Syria, to be put at its original location. So it is technically a restoration attempt, rather than a reproduction since it may be "the" original monument from now on.

There is one last problem with the model created by the IDA. It has never been provided to the public, and unfortunately, the Arch of Palmyra is destroyed and access to CH is considered a basic human right. There are a couple of photogrammetry scans of the arch in 3D model repositories. One of them is Sketchfab (Figure 2.3.), which was founded in 2012 and, as of 2024, still has numerous 3D models freely accessible to the public (Flyyn, 2016). The other one is Scan The World (Figure 2.4.), which is based in the United

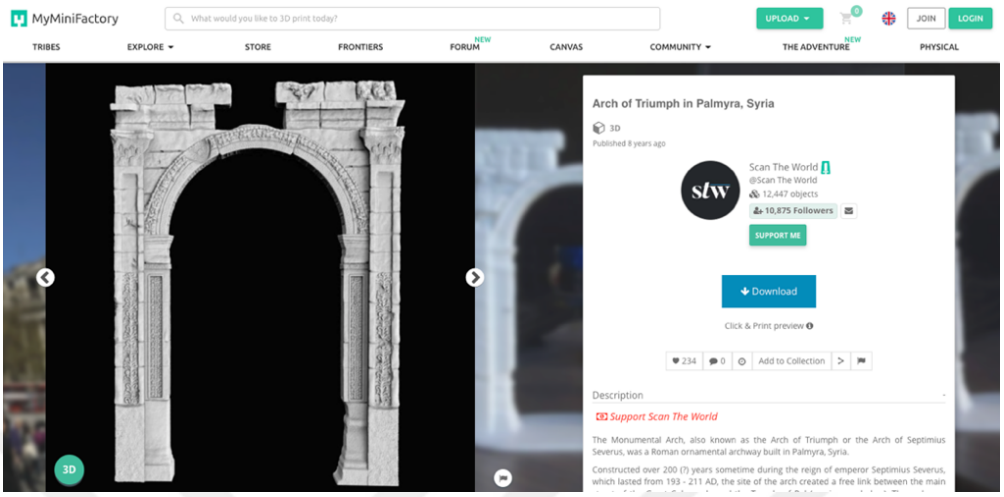
Kingdom and with more than 12,000 3D models of CH artifacts, it is one of the largest repositories in the world about the subject (Scan The World, 2016). Both of these models are created by the photogrammetry method, taking numerous photographs and letting software stitch them together to make a 3D model from the reproduced arc being exhibited at Trafalgar Square in London, which was one of the sites for the reproduced arch around the world.

Figure 2.3. Arch of Palmyra Model from Sketchfab



(Source: *(Sketchfab, 2016), A photogrammetry scan of the reproduced Arc of Palymrya done by Thomas Flynn, shared freely with the public.*)

Figure 2.4. Arch of Palmyra Model from MyMiniFactory



(Source: *(MyMiniFactory, 2016), A photogrammetry scan of the reproduced Arc of Palymrya done by the Scan The World team, shared freely with the public.*)

2.4.3. Research and Accessibility

CH objects can be hard to transport, too delicate to be examined regularly by hand, or in danger of deterioration. With 3D digitization, research on these objects is much safer and repeatable. Granted, when the proper accuracy criteria are met, the objects can be captured to the micron details in every possible angle. With the help of 3D printing and CNC machining, as well as different manufacturing techniques, objects that are not permitted to be touched can be in the hands of interested parties (Neumüller et al., 2014).

Digitization of CH in both 2D and 3D forms has another advantage, which is, with the help of worldwide internet infrastructure, the possibility of transferring just the files for examination. This eliminates travel necessity and danger for both the object and for the researcher. But 3D digitization, with the help of the aforementioned manufacturing techniques, has the ability to replicate an object in its entirety. A case study done by Università Iuav di Venezia in 2018 shows how versatile this approach can be (Ballarin et al., 2018). Using an archeological finding of the upper Palaeolithic, the team first scanned the object with a triangulation-based laser scanner. The result is accurate up to 40 µm,

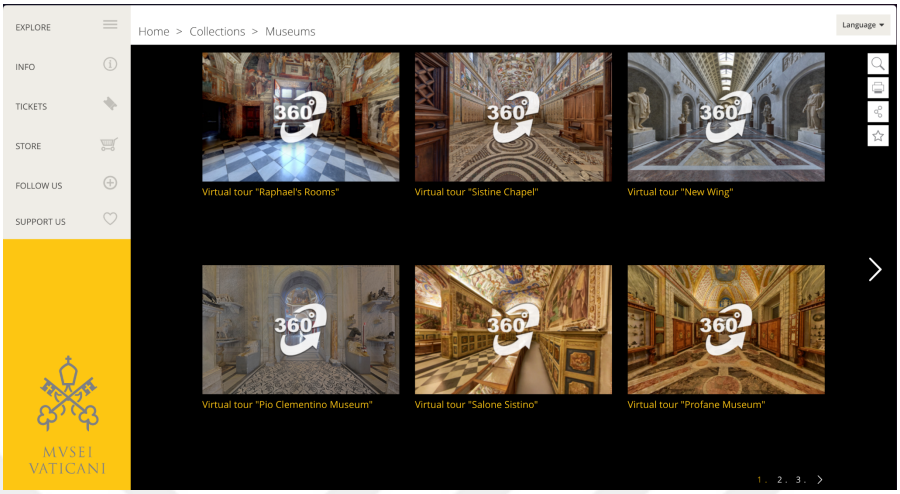
with a slight variation. With further digitization, the file had a standard deviation of 0.474mm, less than half of a millimeter. After that procedure, the team chose to manufacture four different 3D models through reproduction, three of them from the same machine with different materials, and one by sending the file to an additive manufacturing company to receive a colored copy (Ballarin et al., 2018). Their purpose was to find measurement deviations between different materials and manufacturing techniques. Considering all the budgetary and availability options regarding the manufacturing techniques, it is indeed possible to replicate an object to a less than 1 millimeter tolerance in detail and this research proves that. It is even possible to send the file to another continent and through local manufacturing techniques, the reproduced object may be examined thoroughly.

Around the world, there are numerous 3D printing services, both professional and consumer grade, and the digitized file is usually all that is needed to create a replica of the original object. With the inclusion of direct communication between institutions, instead of traveling long distances between countries or continents, researchers can access CH objects relatively easily.

2.4.4. Virtual Displays and Tours

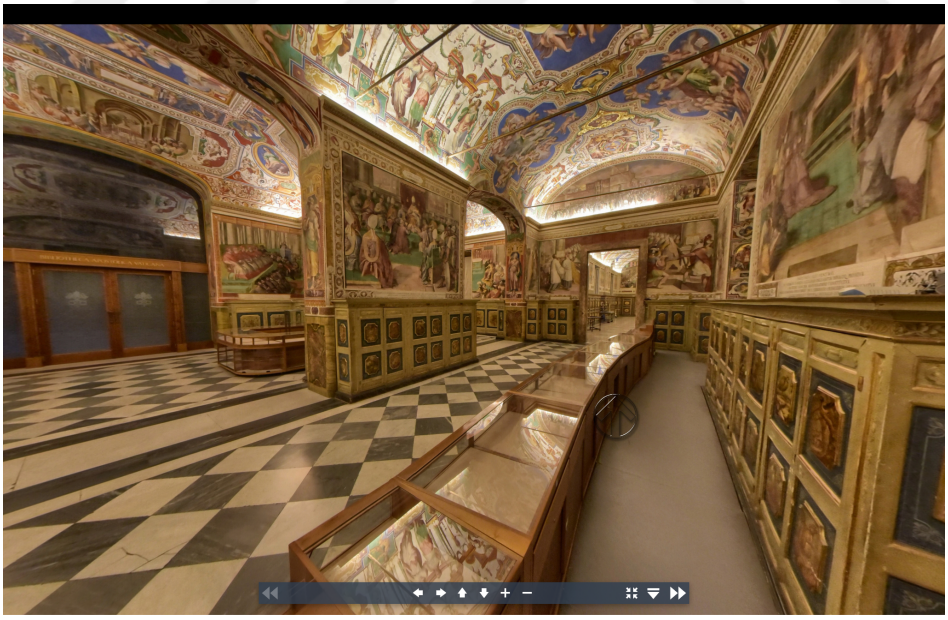
Digitization, while it is being used in brand new experiences for CH practices, can also be used to mimic experiences that can be done in reality as well. Standalone virtual displays or whole virtual museum tours are strong use cases for digitization (Malik et al., 2021). Although 3D digitization creates a new level of immersion and interactivity with virtual display technologies, 2D digitization is a viable and common practice among museums. Vatican Museums, which has 26 different museum sites as well as archeological areas (Figure 2.5), has a virtual tour catalog, which as of 2024, lists 14 different locations (Figure 2.6.). That is more than half of the museums that can be visited physically (Vatican Museums Web and Multimedi@ Office, n.d.).

Figure 2.5. Vatican Virtual Tours Homepage



(Source: *(Vatican Museums, 2024), A selection of 2D virtual tours provided by the Vatican Museums.*)

Figure 2.6. Vatican Museums Interface Example

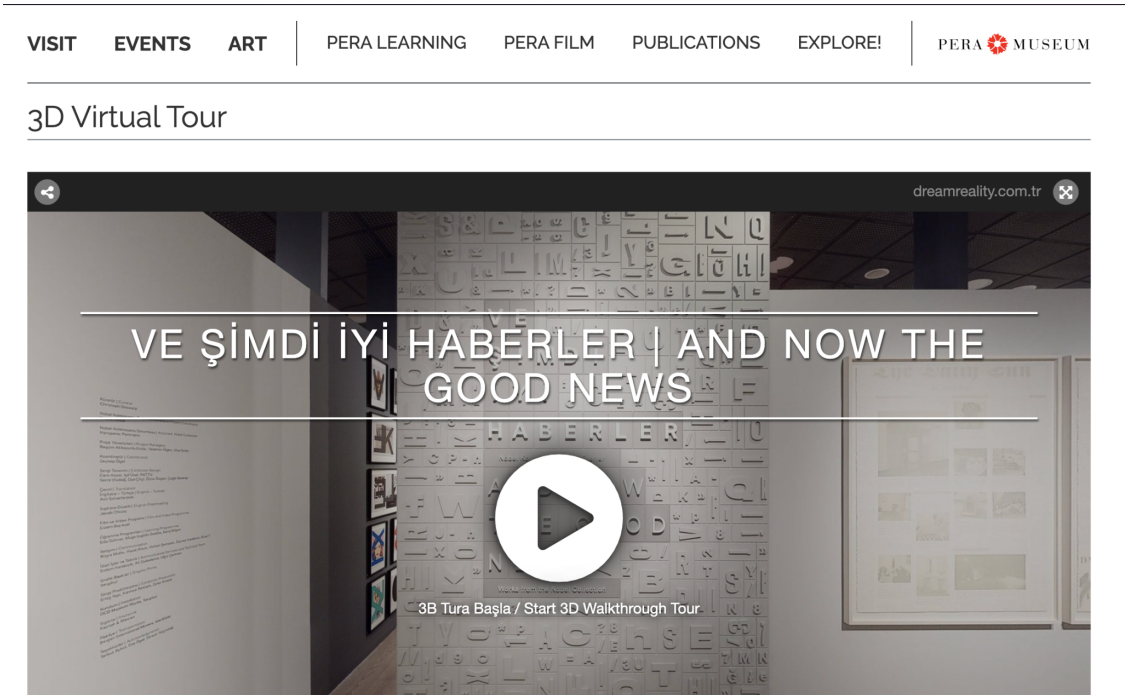


(Source*: (Vatican Museums, 2024), An interface example from Salone Sistino tour.*)

Virtual displays and virtual tours had their peak popularity with the COVID-19 pandemic. Throughout the pandemic, access to more than 90 percent of World Heritage sites was

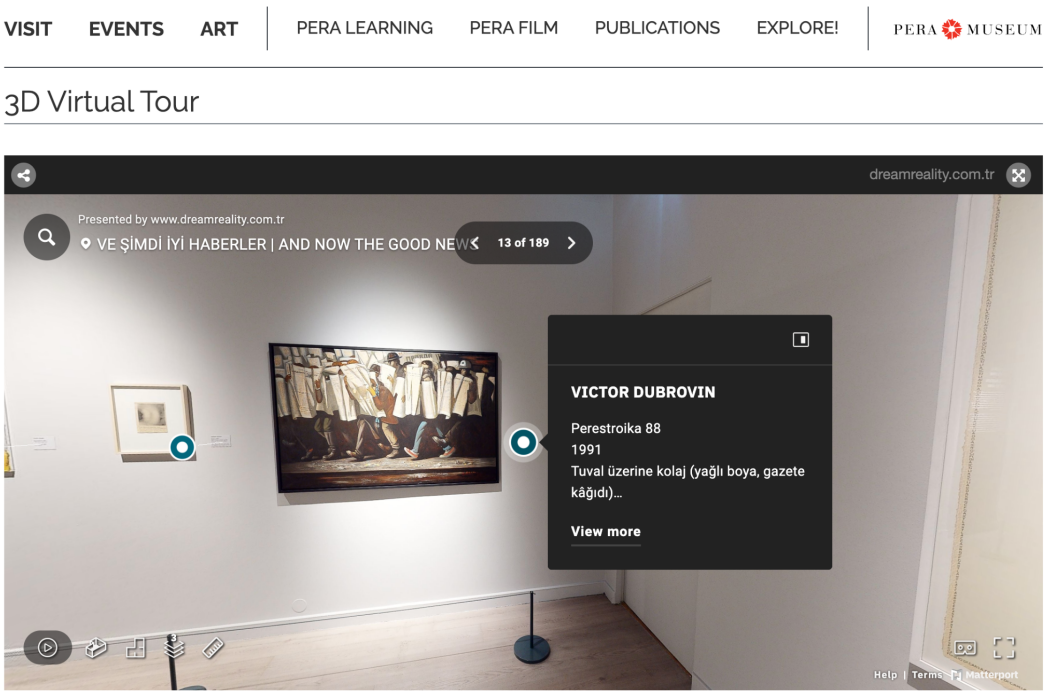
either fully or partially blocked (Quintero, 2020). The examples from the pandemic era, like the Vatican Museums or virtual displays of Pera Museum in Türkiye (Figure 2.7.), which include virtual displays with annotations and extensive information (See Figure 4.7.), are mostly 2D digitization. Their virtual displays are, although labeles as 3D, also 2D which means only the planned sides of the objects are visible (Pera Museum, 2022).

Figure 2.7. Pera Museum Virtual Tour Splash Screen



(Source: *(Pera Museum, 2024), The start screen of an alledged 3D virtual tour.*)

Figure 2.8. Pera Museum Virtual Tour Information Block



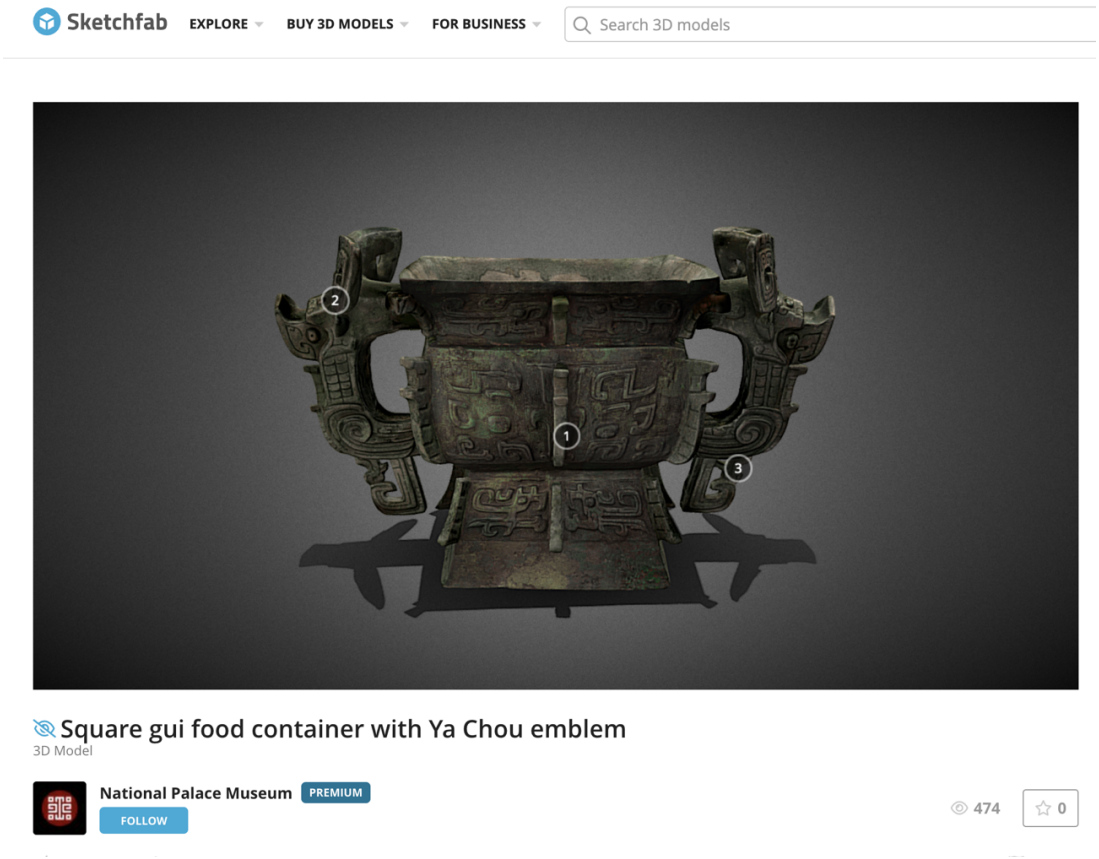
(Source: *(Pera Museum, 2024), An interface example and additional information block that can be clicked and examined by Pera Museum.*)

The usage of 3D digitization for virtual displays is, relative to 2D, highly immersive. Since the digitization is being made as a whole, every angle and every detail of the object is, if preferred, captured. This means that not only can the user manipulate the camera angle relative to the object, but curators can also add related information to the specific parts of the object to be revealed.

There are either proprietary or commercial solutions to virtual displays. The most prominent and widespread display solution is Sketchfab. Users can upload their 3D models and add annotations whether off (Figure 2.9.) or on (Figure 2.10) to specific parts, which enriches the experience while retaining a full 360-degree viewing experience. In 2D digitization and virtual tours, the viewer is confined to the photograph library that was constructed. However, for 3D digitization, since a complete model has to be captured with its technical properties, if it is allowed, the viewer can choose to inspect different

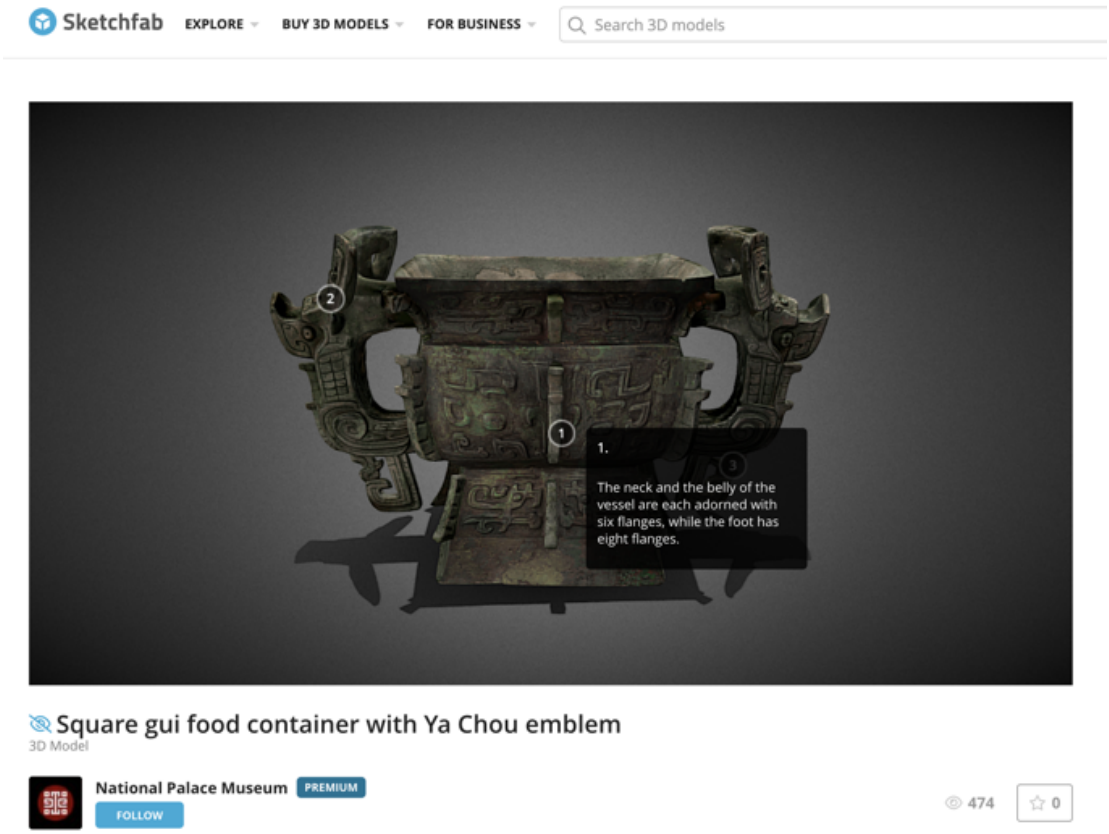
specifications. In Sketchfab, there is a sidebar called Model Inspector and through that tab the viewer can see the MatCap (Material Captures) data, glossiness, or wireframe count and normals data (Figure 2.11.). These are important for the interested viewer since they show the base detail quality and a presumed accuracy of the 3D model, therefore choosing a proper solution for the case-specific problem.

Figure 2.9. National Palace Museum Annotations Off Example



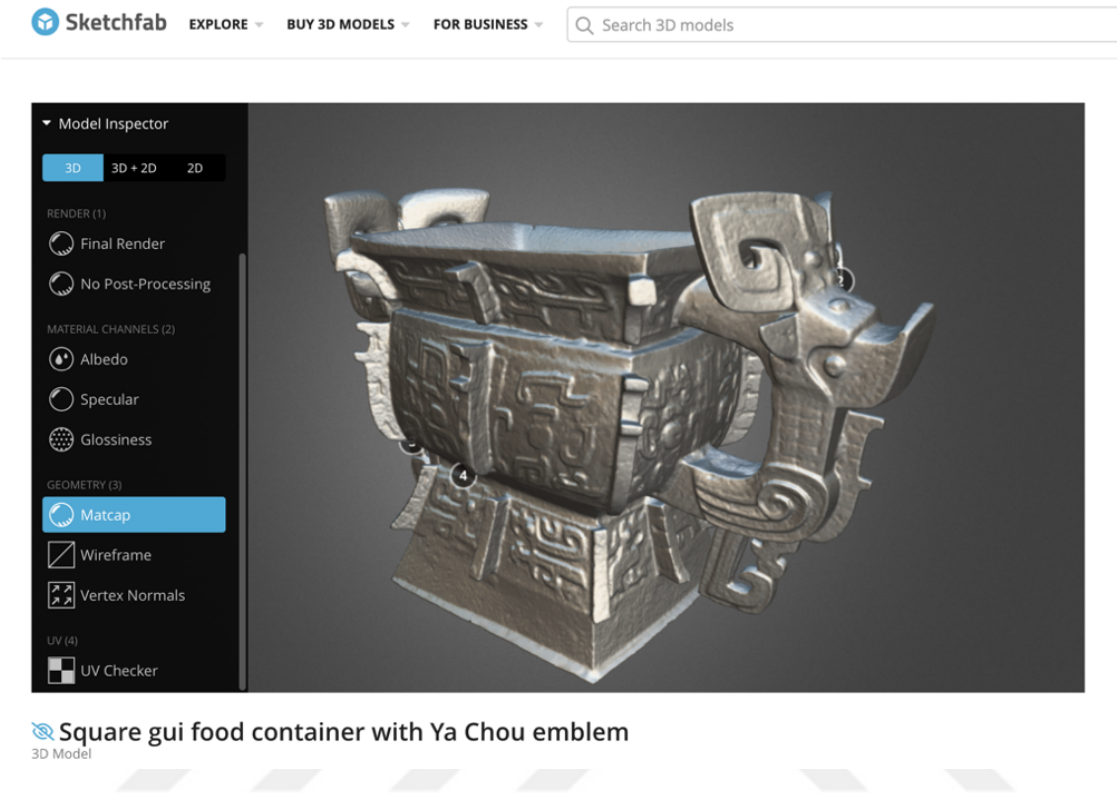
(Source*: (Sketchfab, 2021), An example from the collection of National Palace Museum from Taiwan, without the annotation system turned on in Sketchfab.*)

Figure 2.10. National Palace Museum Annotations On Example



(Source: *(Sketchfab, 2021), An example from the collection of National Palace Museum from Taiwan, showing the annotation system in action.*)

Figure 2.11. Sketchfab MatCap Option



(Source*: (Sketchfab, 2021), An example of the Inspector system, showing explicitly the MatCap option embedded in Sketchfab.*)

Virtual tours in 3D digitization are technically more challenging than 2D digitized tours, because all the 3D objects have to be in a custom, museum-like space in order to be traversable. A way to create these experiences is through Virtual Reality (VR) goggles, with this option custom 3D spaces can be filled with proper 3D CH objects and either a narrative or a freely traversable tour is possible. Other than VR, experiencing 3D CH monuments is possible as well. A recent and prominent example is the Notre-Dame Cathedral in Paris, France.

After the devastating fire in 2019, while the restoration process was underway according to documentation, video game company Ubisoft, the developer and the publisher of the title Assassin's Creed: Unity, offered to share a highly detailed 3D digitized model of the Notre-Dame which they used in their game, with the French officials. Also with its

knowledge and expertise, Ubisoft also offered to donate €500,000 to the cause as well (Handy, 2023).

Due to its significance in the game, Ubisoft meticulously crafted the Notre-Dame 3D model with detail. They used photogrammetry for the basis of their work and then throughout the photographs, drawings, and documentation the model has been enriched.

Although Ubisoft had extensive work for the Notre-Dame, its data is unfortunately not usable for the French government for the restoration. Since Unity is a videogame and Notre-Dame is a place that players can traverse and complete objectives, it was created as a video game level. Because of that, there are numerous changes to the original structure that makes some video game actions or objectives possible. There is also the concern for copyright and due to this controversy all of the statues and stained glass paintings are custom works appropriate for the setting (de Rochefort, 2021).

A remixed or reimagined 3D digitization may not undertake the whole restoration of the Notre-Dame, but the importance of Ubisoft's model comes from the connection between the public and the history. Ubisoft, with all its offerings and donations also made Assassin's Creed: Unity free for a week in 2019 (Hanussek, 2024). Since the doors of the cathedral were closed, people were able to visit and traverse the building in their own way. Assassin's Creed: Unity and its Notre-Dame model may not be a prime example of an intended virtual tour. However due to unfortunate circumstances it was a valid experiment and with the right technical accessibility, since gaming PCs and video games consoles may be considered relatively high-budget solutions, it is a possibility in future iterations.

2.4.5. Augmented Practices

Digitized CH objects may form a standalone exhibition, or also be complementary pieces to the physical objects within museums to augment their effectiveness, as well as understanding. This practice, with photography, has been around for a long time. It has

been possible to give details about the dig site, or the previous state of the related CH object with a series of photographs alongside exhibitions (Walsh, 2007).

With the increased versatility of 3D digitization, delicate pieces can be digitized and put as a display next to the encased objects in order to amplify interaction. Touch screens with the 3D models of physical objects can be rotated, zoomed in and just like virtual tour elements, annotations can be added to further amplify the effect (Elias, 2019).

The act of augmenting stationary or physical objects is not solely to the hands of museums anymore. In 2018, a group of independent artists created an augmented playground on the fifth floor of MoMA, New York's Museum of Modern Art. Only through the MoMAR Gallery app, which could be downloaded freely, Jackson Pollock's paintings change into remixes of themselves, or whole new experiences (Katz, 2018). There was a rebellious intent, which aimed to disrupt the modern art museology with more independent and less-known artists and mediums, behind the MoMAR Gallery mobile app, and that was just part of the story. Whatever the meaning may be, every interaction also strengthens the bond between the viewer and the viewed object, which in this case is a modern art but very may well be a CH object as well. Rijksmuseum, the Dutch national museum in Amsterdam, is using augmentation to let visitors remix existing artworks to create "new masterpieces". Since 2014, Rijksmuseum has held numerous annual design competitions. The museum uses its extensive website and thoroughly cataloged images to let young artists express themselves. This is possible with the hand in hand work between the physical and the augmented digital aspect (Rühse, 2017).

2.4.6. Reproduction

3D digitization is also used in reproducing current or long-lost objects, monuments, and sites. Reproduction prior to 3D digitization and automated systems like CNC milling or 3D printing (formally known as additive manufacturing) were present. Plaster casting, sketching, and even photographs are considered both 2D and 3D reproductions of the

original objects. But with 3D digitization, modifying the source file to the needs of the case is possible.

These alterations may, but not only, include mirroring, scaling, adding or subtracting details. This idea goes hand in hand with documentation and restoration, but in reproduction some artistic liberties[4] may be taken due to scarce data.

The recreation of a Temple Lion for Harvard's Semitic Museum is a valid example in this matter. There should be two ceramic lions to accompany the goddess Ishtar. One of them is quite well preserved, the other is unfortunately missing a substantial part of its body (Figure 2.12.). But through 3D digitization, it can be virtually restored and be whole again. Either by digitally reconstructing and manufacturing in order to complete the fragmented lion, or by constructing the mirrored lion altogether to give visitors a sculptural context (Neumüller et al., 2014).

[4] When restoring the objects, if there is insufficient data about the original form, an expertise is needed to gather relevant information and reimagine lost details. This is also valid for 3D digitization, when an algorithm fails to construct details from photographs an artist may need to model details from scratch. Panoramic image-based modeling, which has been defined previously, is an example.

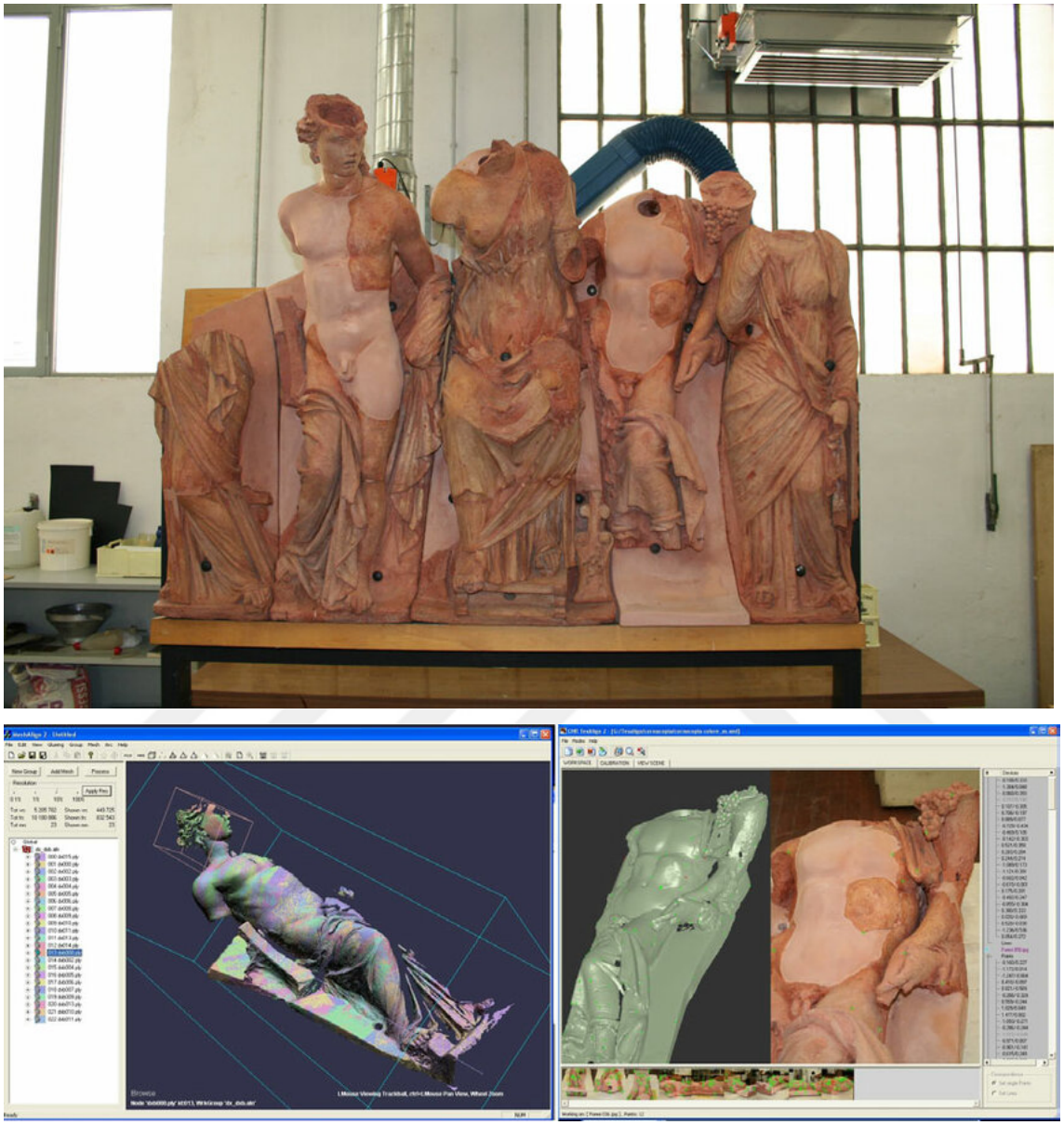
Figure 2.12. Two Lions of Ishtar



(Source*: (Harvard Art Museums, 2021), Two Lions sculpture from the Temple of Ishtar, one is relatively well preserved and the other one missing the head.*)

In reproduction, the artistic liberties may be based on the trace evidence and it can be used in coloring and/or modeling. Assembly of Gods of the Temple of Luni is a fragmented and damaged statue collection and although it has been restored to a scale, there are parts that are completely destroyed. However, through 3D digitization and modeling techniques, an hypothesis can be created in the virtual world with no damage to the physical object (Figure 2.13.). Through following the trace evidence, even the color of the original statue can be recreated (Scopigno et al., 2011).

Figure 2.13. Assembly of the Gods Statue and Recounstruction



(Source*: (Scopigno et al, 2011), showing the fragmanted relief and tools used for range maps and image registration.*)

Another approach is to create a haptic baseline for education. Scaling is a possibility when it comes to digitization and reproducing CH objects in a comprehensible scale creates a big benefit. Scaling down objects or contraptions to be handheld or scaling up details to be shown more intricately is a powerful tool. The importance is, all these modifications require meaningful reasoning, mostly to “enhance meaning” (Neumüller et al., 2014).

2.4.7. Other Use Cases

Apart from the described use cases, there have been new categories emerging with the increased familiarity of 3D digitization. Most prominent and established way is remixing, which is tied to remixability, which is a transformative process where the information and media can be shared, recombined, reformed and added upon to create new ways of structures, idea seeds, amalgamations (Manovich, 2005).

When a digital CH object is being restored, in a sense it may be remixed as well. Since not every detail of an archeological remnant is present and accountable, when previously defined artistic liberties are taken into consideration, an object becomes a new structure itself. However, the remixing as a use case has more artistic or educational aspects to it. In Rijksmuseum, remixing is being used to make visitors more engaged with the objects and the museum itself to create a bond for the future (Rühse, 2017). In an educational sense, remixing can be used to make a 3D CH object manufacturable, therefore creating a tactile and sensual object to be understood (Neumüller et al., 2014). In this sense, remixing CH objects may create a way of self-learning (Younan & Treadaway, 2015).

Even a born digital object may be considered as a cultural heritage, not every creation is a masterpiece (Younan & Treadaway, 2015). And yet, it doesn't diminish the impact of remixing throughout the artistic community. As an artistic expression and defiance, remixing has been used in MoMA for an exhibition, an unofficial one at best to give voice to less-renowned artists a place through existing pieces (Elias, 2019). Not just for creating an effect, for artists remixing creates a bond just like the bond between the visitors and the museums. Mario Padilla, a Mexican artist feels like having an ongoing relation with an object from the past through remixing. The same connection emerges for an Irish artist named John Rainey, who also remixed a 3D model of a ceramic figure (Younan & Treadaway, 2015).

3D DIGITIZATION PRACTICES AROUND THE WORLD

As it was stated in Chapter 1, there are numerous steps in the 3D digitization process and every step has its own variety due to technological advancement, digital obsolescence and technical knowledge. It is possible to find case studies in the literature research from choosing a CH object, digitizing it with an off the shelf solution, whether it may be laser scanning or photogrammetry of any accuracy level, and in the end presenting the final data. However, doing it on a relatively larger scale, meaning creating a collection, as a standalone or an ongoing project is another matter.

There are understandable constraints like time and budget, both affecting the process immensely. There is also the possible problem of relaying know-how, especially if the digitization is part of a funded project and the knowledge is outsourced. However all these possible disadvantages are rhetorical. They are, by all means, real and can happen in any digitization project but the frequency or the possibility of them happening is still a question. To at least open a door to answering these questions, Chapter 2 of this research is dedicated to interpreting and analyzing real world data that was collected from real world institutions around the world.

3.1. Grounded Theory

The data has been gathered through an online survey and in order to interpret the data, Grounded Theory was chosen. In a simple manner, ground theory is defined as the theory that comes from the data. Which means it is formed with the data hand in hand. The theory, with its components and constructs, are grounded to the data. Hence the name, grounded theory.

There has been a search among theories which this research can be built upon, and the major reason for selecting grounded theory is that 3D digitization is a relatively new area within cultural heritage. Therefore, even though there have been numerous articles and

papers regarding the overall subject, there haven't been enough resources dedicated to a subset of topics including standardization that can be theorized upon. In essence, to reach a proper idea of standardization within the research the foundations of grounded theory suited best.

In grounded theory, data collection, analysis and theory formulation are working together and not separate. It starts with the collection of data, then a preliminary analysis is made to create a guide. That guide is used to further collect more data and then an extensive analysis can be made. If the desired goal is not reached, another step of data collection and further analysis is possible. The first analysis step which is open coding is where the data and its relevant categories are identified. Then comes the axial coding, where the categories are refined and sharpened. Third step is selective coding, where the central category or variable is defined with all the other categories surrounding it. These coding steps ensure that the analysis and data collection are in relation and able to evolve (Şen, 2006).

3.1.1. Open Coding

In order to place the idea of standardization into the 3D digitization of CH, the dissection of every step of that procedure seems necessary. There are apparent advantages to be gained for digitizing objects and these had been laid out at the Chapter 1 of this research. And yet, there are disadvantages within these steps that have the possibility of registering the work that has been done invalid. To define possible disadvantages within the digitization procedure, literature research is a necessity and through that research a list of open coding categories can be assembled. As it was detailed in Chapter 1, the digitization process consists of getting the data, storing that data for later use, and finally accessing it for usage (Figure 3.1.). Every step of the process has its challenges and these create the basis of coding categories.

While collecting the data, scanning technique is a major category that later defines and affects other steps as well. Every digitization process has strengths and weaknesses within

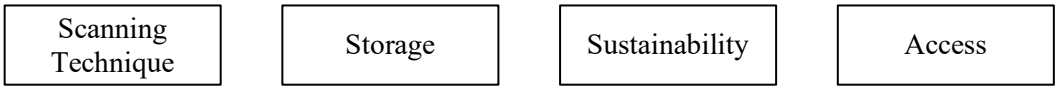
their technical vocabulary, which can also be defined as advantages and disadvantages. One technique may be easy to use but lacks dimensional accuracy, like photogrammetry, or it may be hard to set up and lacks texture detail but relatively much more accurate, like laser scanning. In order to evaluate the idea of standardization within scanning, this research has to collect the viewpoints of the institutions.

A similar conundrum is apparent for storage as well. When the level of detail increases, so does the size of the data, therefore it is harder to both store and to access. Metadata standards and requirements are a part of this discussion too, since they are practically the librarians of these collections. Also, in order to get much detailed data from the CH object, the hardware requirements increase exponentially. This affects entry to the digitization process altogether as well as the continuation of the digitization process.

When digitizing low volume CH collections, these disadvantages may not be incredibly effective. However, as the collection grows, the requirements also increase. A CH institution may choose to create a small scale collection with a grant or a governmental agreement and with the help of industrial specialists due to their know-how about the subject. This both helps the institution about an entry point for the process, as well as gathering much valued know-how regarding digitization. In addition to these, gathering expensive equipment before fully committing to digitization may be impractical and this agreement may help with that as well. The problem is, in some projects the digitization process may cut short and the institution may not get the know-how they have much needed. These breaks within the knowledge may create unfinished collections or in the future, outdated file and data sets which are prone to data obsolescence.

After gathering and storing the data, it is important to give clearances to the people who are interested in accessing it. The problem lies with the rights of the digital files, since they are, in their own sense, cultural heritage objects themselves but also part of the respectable collections they are from. The rules of access are another crucial step where a standardization may be needed and it must be examined through the collection of real world data.

Figure 3.1. Open Coding Categories



3.1.2. Axial Coding

After gathering the open coding, another sweep of the data that was done to create a preliminary Axial Coding. Since in grounded theory, the data collection and theory progress are side by side, every collected data set can be subject to re-evaluation.

As for the scanning technique, the importance seems to fall into the accuracy of the objects. There have been different studies which are testing the dimensional accuracy of the objects. Also in technical articles scanning techniques are usually categorized by their accuracy and capabilities, like ability to capture textures or being able to be used with commercial drones. Due to this trend that is familiar for the researchers, the category then evolves from scanning technique to accuracy of the object.

The practical application of storage is divided into two distinct categories. First one is metadata and that is the most apparent category that is related to standardization. There have been numerous metadata standards for museology and although different institutions may use different types of metadata, at least in this category a well defined system is available for every need. Therefore the question of standardization is not necessary for metadata.

Digital obsolescence on the other hand, is a messier category to handle. Computer operating systems and data file formats change periodically but their change trajectory is a question worth asking. Regarding an uncertain future, the steps being taken to future proof existing digitized data is a major issue for museology and archival institutions. In order to ask this question, the storage category morphs into digital obsolescence.

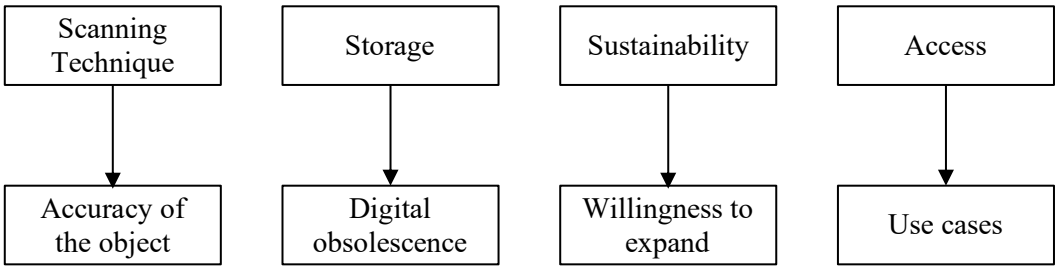
Singular or small scale 3D digitization attempts define the advantages and the disadvantages of different methods but for creating and maintaining a vast collection on

3D digitized objects is relatively uncommon. Two of our survey participants, Smithsonian Museum and Scan the World initiative, which holds more than 1,000 objects in their collection, are rare in their position. Ranging from less than 50 to a couple hundred, most 3D digitized collections are relatively small. On the other hand the category, sustainability, is incredibly broad and even if it is possible to define reasons to continue digitizing objects, weighing their importance to the matter is harder. Instead of sustainability, the more accurate way of examining the category is actually willingness to expand. There are different considerations for this category, from budgetary limitations to transferring the know-how between industry experts and institution employees. All these considerations have been formed into their own survey questions, but as for the category, an umbrella term of willingness to expand has been chosen.

As a category, access has both technical and legal meaning. Cultural heritage, defined by UNESCO, is a human right and digitized objects are not exempt from this definition. However, the legal aspect of CH access is a more broad discussion than digitization itself. Therefore a focused scope must be taken in order to define the category of access.

There are several use cases that facilitate access to digital CH and these use cases, in their own boundaries, have something of an agreed upon approach. Through popular platforms such as Sketchfab or MyMiniFactory, where a CH object can be both displayed and be shared with the people, there are certain requirements that an object must have. These ideas could create a baseline for a standardization within this category, therefore instead of access the revised category is use cases (Figure 3.2.).

Figure 3.2. Axial Coding Categories



3.1.3. Survey and Data Collection

In order to collect real world data from institutions which have 3D digitized collections open to the public and also willing to cooperate, a survey was created according to axial coding. The survey is titled *3D Digitization of Cultural Heritage Artifacts* and it consists of 22 questions. These questions have been dispatched into four sections and they aim to give some context to how institutions are operating. Through that operation, the research aims to find arguments for the existence of standardization.

It has to be remembered that most of the institutions have their internal affairs private regarding these procedures. Questions in the survey include budgetary concerns, time and money investment issues, whether the institutions are willing to continue this work or not and these subjects are not always open to the public. Same can be said to get certain procedures and agreements between institutions and industry experts and/or companies. Not every institution has its own digitization department and commercial agreements tend to be private.

In order to protect the confidentiality of institutions and be able to get answers, the questions in the survey were created meticulously. The anonymity of the responders is also an importance and there has been no steps taken to jeopardize that. Admittedly, these precautions may limit the questions regarding their directness and a more diverse road may be taken. However, in order to understand the place of standardization, this approach was considered as the most viable one for this research.

The candidates have been chosen based on their open 3D digitized collections and how they present them. A minimum object per collection has not been selected, but the presentation of the collection and its place within the institution (whether via a newsletter or a permanent place on their website) was crucial. If it is impossible to find through conventional ways, it was considered non-existent.

The second concern was about the locations of the institutions. It was aimed to be as multinational and multicultural as possible. There are, in total, 10 participants to the survey (Table 3.1.).

Table 3.1. Survey Participants Around the World

	Country	Instutition
1	United Kingdom	Scan the World
2	Türkiye	Pera Museum
3	Denmark	SMK Staten Museum
4	Ireland (United Kingdom)	The Hunt Museum
5	Australia	Australian Museum
6	Scotland (United Kingdom)	Scottish Maritime Museum
7	Catalan (Spain)	Museu Nacional Arqueològic de Tarragona
8	The United States	The Smithsonian Instutition
9	Russia	The State Darwin Museum
10	Poland	Malopolska Cultural Department and Assembly of Museums

The participants include natural history museums, art museums, solely 3D digitization focused non-profit organizations and governmental and private institutions which are responsible for multiple museums. There are both private and public museum in the list of participants. Pera Museum, which is a private museum founded by the Suna and İnan Kıraç Foundation, was inaugurated in 2005 and began their 3D collections by digitizing their “Kütahya Tiles and Ceramics” permanent collection (About Us, n.d.). After that, they proceeded to the other permanent collections as well, being a pioneer in Türkiye. Distancing from fully private institutions, The Smithsonian Institution and their vast

collection of museums are a unique public-private partnership that was established in 1846 and defined as the world's largest museum, education and research complex (Our Organization, 2017). Their 3D collection, titled Smithsonian 3D consists of pieces from their various museum complexes and one of the oldest 3D digitization undertakings in CH scene. The Hunt Museum is also a public-private partnership which is a long legacy from John Durell Hunt and his wife Hertrude Hartmann. (Our History, 2021). Inaugurated officially in 1997, the Hunt Museum has entered to the 3D digitized world in 2018 and still expanding their collection even in 2024 with new pieces. The Hunt Museum has collaborations, such as "Scanathon" which happened in 2021, with another participant of this research Scan The World (The Hunt Museum's First Scanathon, 2021).

From private to public museums, Australian Museum is the first museum established in Australia in 1827 and today the museum takes on dual roles in research and education (History, 2020). Although having more than 21 million pieces in its vast physical collection, Australian Museum houses a relatively smaller 3D collection and their public collection was updated in 2022 (Collection Objects in 3D, n.d.). Scottish Maritime Museum, which is a public museum entity and consists of two buildings located in Irvine and in Dumbarton, has a mission of preserving nation's maritime past and present through a variety of historic vessels, art, personal items and shipbuilding tools (Who We Are, 2019). The 3D collection of Scottish Maritime Museum is relatively smaller and has been a work of collaboration with a third party organization. Unfortunately, there are no new objects being added as of writing this research, however the museum was kind enough to both participate and share the context behind their planning of 3D digitization. Museu Nacional Arqueològic de Tarragona (The National Archeological Museum of Tarragona) began its life as a provincial public museum in the first half of the 20th century (History, 2018). Their 3D digitized collection dates back to 2020 and consists of both small to medium objects and large pieces like column heads (Global Digital Heritage, n.d.). The State Darwin Museum was established in 1907 as an educational museum and is labeled as the first museum focused on biological evolution in the world (State Darwin Museum, 2019). Due to the museum's nature, the 3D digitized collection consists of biological specimens and diversifies itself from other participants of this research (State Darwin

Museum, 2017). Malopolska in Poland has an ambitious project called Wirtualne Muzea Małopolski (The Malopolska's Virtual Museums). The initiative aims to digitize most of the objects in Malopolska region and they have more than 42 museums' collections in its database (Malopolska Institute of Culture, 2021). When asked if they are willing to participate in the survey, the response came from Malopolska Cultural Department and Assembly of Museums, therefore the participant is listed under this name. Although their collection began forming after 2010, according to their statement their planning dates back to the early 2000s, meaning they are one of the oldest collections to at least be perceived. SMK Staten Museum in Denmark is a public museum, which eventually inherits the art collection of the monarchy of Denmark after the country was introduced to democracy in the mid-1800s (Statens Museum for Kunst, 2018). SMK Museum began creating their 3D collection in 2018 in a collaboration with another participant of this research, Scan the World (Vellam, 2019). The last participant, Scan The World, is a London-based initiative which in their own statement, aims to open source cultural heritage one 3D printable statue at a time. Including two of the participants in the survey, The Hunt Museum and SMK, Scan the World has collaborations with more than 50 institutes and their aim is to share CH objects with the world, freely. Scan the World is mainly a crowdsourced project, meaning anyone can be a benefactor through their website and their collection is entirely free to access through MyMiniFactory website (Scan The World, 2014). Apart from crowdsourcing, Scan the World has collaborations with Google Arts & Culture, and Wikipedia, as well as 3D scanning equipment manufacturers like Artec 3D (Perera, 2023). In its structure, Scan the World differs from other participants and there are only a few similar institutions around the world like them. A prominent and yet not a complete copy of an example is Global Digital Heritage (GDH), however in spite of all the attempts at communication it was not possible to include them in the research. Although having a complex administrative structure stated in their public website, GDH also collaborates with different institutions to digitize their objects and share them with the public (Team, 2018).

Including GDH, attempts to expand the list of responders were unfortunately futile, but due to the open nature of 3D collections there has been analysis through the object that

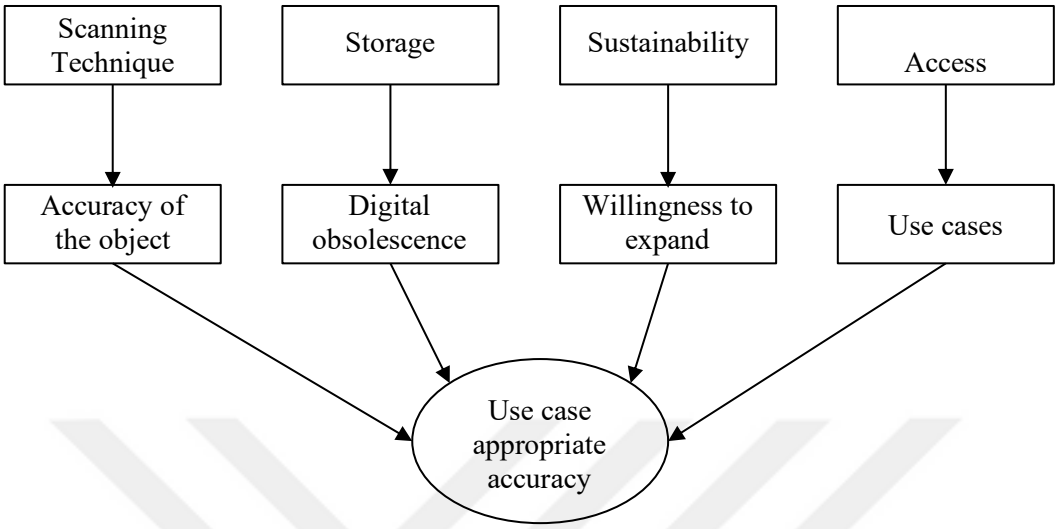
has been presented within institutions' websites or their respective accounts on Sketchfab. As an example, there have been attempts to communicate with the Matsudo Museum (Japan) and National Palace Museum (Taiwan). However, both of these institutions, regardless of the attempts that have been made, did not respond to any communication and yet some of their 3D collections are freely accessible and detailed. Through Sketchfab and its standardized interface, it is possible to interpret the technical capabilities that are available to these institutions. Unfortunately, it is impossible to determine how these institutions are handling the internal affairs when it comes to 3D digitization. Whether they have been working with industry professionals or have their own digitization departments. Nonetheless, getting even a partial data is crucial to this research in order to understand how different cultures handle the process.

All the questions and answers of the survey, except one, can be found in Appendix B. The one in exception is the voluntarily given email addresses, in case if further contact may be an option. Due to confidentiality reasons, that part of the survey is redacted.

3.1.4. Selective Coding

After collecting the data through survey and website examination, a new set of coding is needed. The central category derived from the data is *Use case appropriate accuracy* (Figure 3.3.). This category prioritizes not the digital object that was created, but the person who is experiencing it. Therefore, the idea of standardization is not just related to the CH object, but to the person who is experiencing it. It is not there just to meet criteria about the digitized object; it is there to ensure that a proper experience is presented to the visitor. To cross-check the data with the selective coding, all the survey questions must be divided into their sections and analyzed.

Figure 3.3. Selective Coding Categories



3.2. Analysis of the Survey Data

The data that was collected from the survey has to be split into sections that make them cohesive. Since it is a qualitative analysis, some questions may be in more than one section and their cross-checks with other questions may create different outcomes. Within the analysis section, since there is one institution from each country, the participants will be represented by their country names. Two exceptions are Ireland and Scotland, which are parts of the United Kingdom yet are named independently.

3.2.1. Administrative Positions

Initial questions of the survey tries to define the people in charge of collections, the age of the collection and the location they operate. These questions primarily show that 3D digitization is still relatively young and institutions are still figuring out its administrative titles and requirements. When asked what their positions are within the institution through a text input field, 3 out of 10 participants answered curator in some form. Another answer, collection officer, also defines a position tied to curation (a person responsible for collecting, cataloging, tagging and storing objects according to the museums'

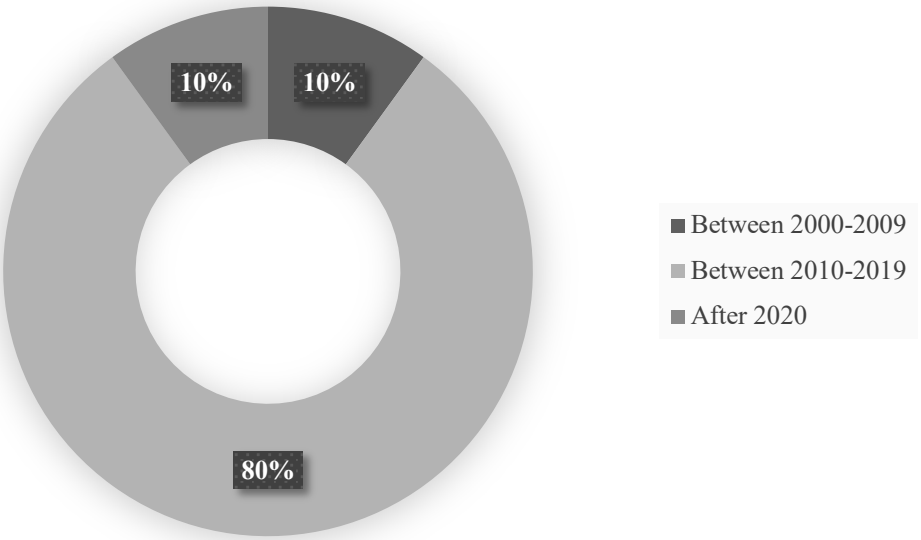
specifications). When all the positions are taken into consideration, 4 out of 10 participants point out a similar position within the institutions (Table 3.1.). However, the title curator is still not a definitive one in terms of digitization. It is an administrative role and not a technical one. Different from the others there are two answers, 3d process supervisor and digitization project manager, which are well-defined and identifiable positions among the participants. These two responses are tied to larger collections. After considering all the answers, there is no clean standard for who should be the one responsible for 3D digitization within institutions. Especially considering the title being technical or administrative tends to affect the answers throughout the survey.

Table 3.2. Answers Given to Question #1

Collection Officer
Founder/Manager
Curator
Digitization Project Manager
Chief Curator
Direction
Curator
Collections and Research Manager
Curator / Senior Advisor of Digital Museum Practices
3D Process Supervisor

The age of 3D collections is mainly tilted towards the answer between 2010-2019. Only one institution began 3D scanning before 2009 and one institution is relatively new to the scene, starting after 2020. The other 8 institutions have started 3D digitization between 2010 and 2019 (Figure 3.4.). 3D digitization has not yet matured; therefore standardization among its categories may be correlated to this fact.

Figure 3.4. Pie Chart of Answers Given to Question #3



Only three of the institutions have their own digitization department (Figure 3.5.) and all of these institutions also have the largest collections (Figure 3.6.). The remaining participants represent institutions that get outsourced services, however their choice of service varies. One participant elaborates "Our partner is another department of the public administration," which means it is a concurrent relationship. It is also a public service entity, which may defeat the purpose of building an internal department. Another participant explains that they are working in tandem with Scan The World, one of the largest 3D model repositories and also an active participant in this survey. Furthermore, one participant defines their digitization connection as "a technician on a consultancy basis to digitize and publish," meaning they also have a consistent relationship with a partner. When these answers are combined, more than half the participants value continuous relationships between their institution and digitization experts, whether they are internal or external. Having continuous digitization partners seems to be an essential factor for the standardization of the process. The established workflow and the consistency seem important to institutions, which all of these responses are also tied to

being still committed to 3D digitization. A clear correlation exists between establishing continuous relations with digitization professionals and expanding collections.

Figure 3.5. Pie Chart of Answers Given to Question #4

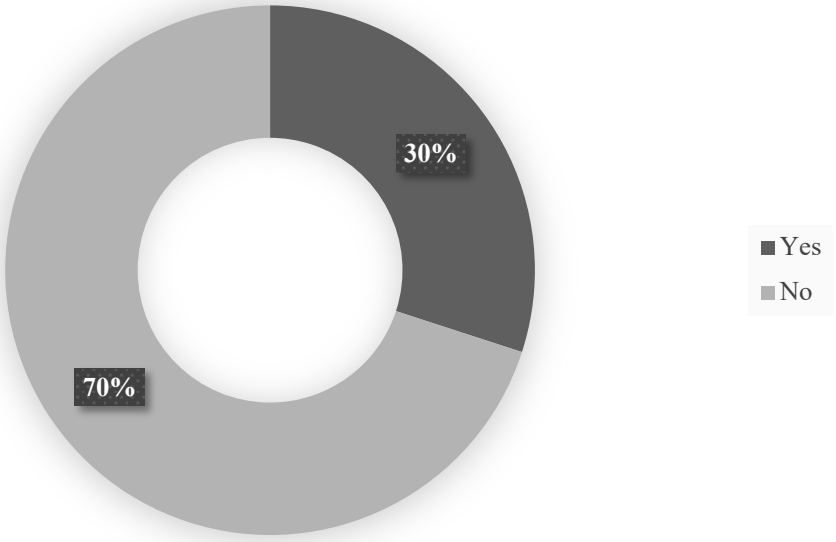
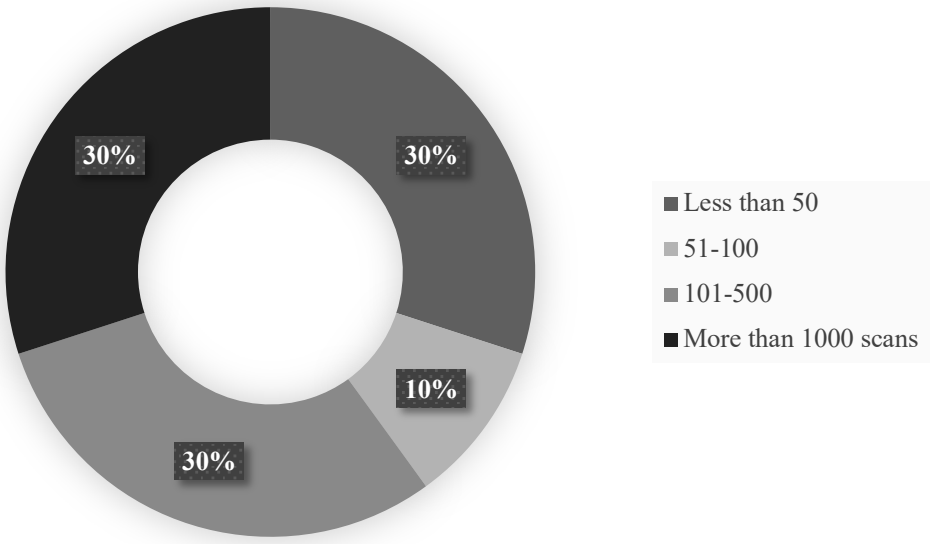


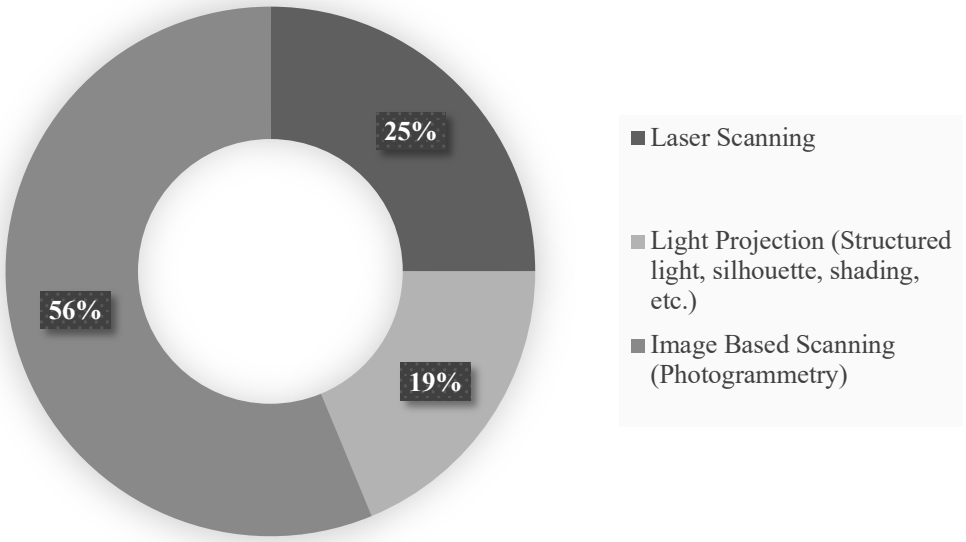
Figure 3.6. Pie Chart of Answers Given to Question #8



3.2.2. 3D Digitization Techniques and Collection Details

Regarding different 3D digitization techniques, the most popular technique is Image Based Scanning (Photogrammetry). Photogrammetry collects geometric data and texture data at the same time, however, when it comes to geometric data, this technique may not be the most accurate. Regardless, when compared to the other techniques, it is the most convenient. Although geometric data can be less detailed, being able to match it with texture data seems to make it favorable among institutions. Several answers contain only Photogrammetry, however, it is not common for any other technique to be the only answer. This means, for some institutions, photogrammetry is the one and only way of digitizing objects, and other techniques are mostly a complement of Photogrammetry (Figure 3.7.). One institution answered Laser Scanning as their one and only technique and that is also the only answer which doesn't include Photogrammetry. That response belongs to Scotland and an email voluntarily sent from the survey participant gave the information that this was a one-time project for the institution. Therefore, they were not in control of the technique or the project as a whole. In terms of standardization, institutions seem to favor a compact, wholesome solution over niche but more accurate techniques.

Figure 3.7. Pie Chart of Answers Given to Question #11



When the answers regarding techniques are being compared to the importance of digitization/scanning accuracy, at first, there seems to be an inconsistency. Because 8 out of 10 participants said that digitization/scanning accuracy is most important, the other two selected somewhat important (Figure 3.8.). This means that, one way or the other, accuracy is an important matter. However, in Photogrammetry, if done poorly or quickly, the overall quality may not be enough to span across multiple use cases like reproduction or highly detailed archiving. In another question, 10 out of 10 participants chose virtual displays as one of their use case scenarios (Figure 3.9.). There is even one institution that selected just the virtual display option, two others selected virtual displays and research, and nothing else. These responses belong to institutions that have less than 50 objects in their collections. This means, for some institutions the need for 3D digitization begins with virtual display use case. The need for texture and the convenience of Photogrammetry, relative to the other techniques, makes it a suitable way of digitizing objects for virtual displays. Considering the use case, the technique and the collection size, the data presents itself consistently.

Figure 3.8. Bar Chart of Answers Given to Question #12

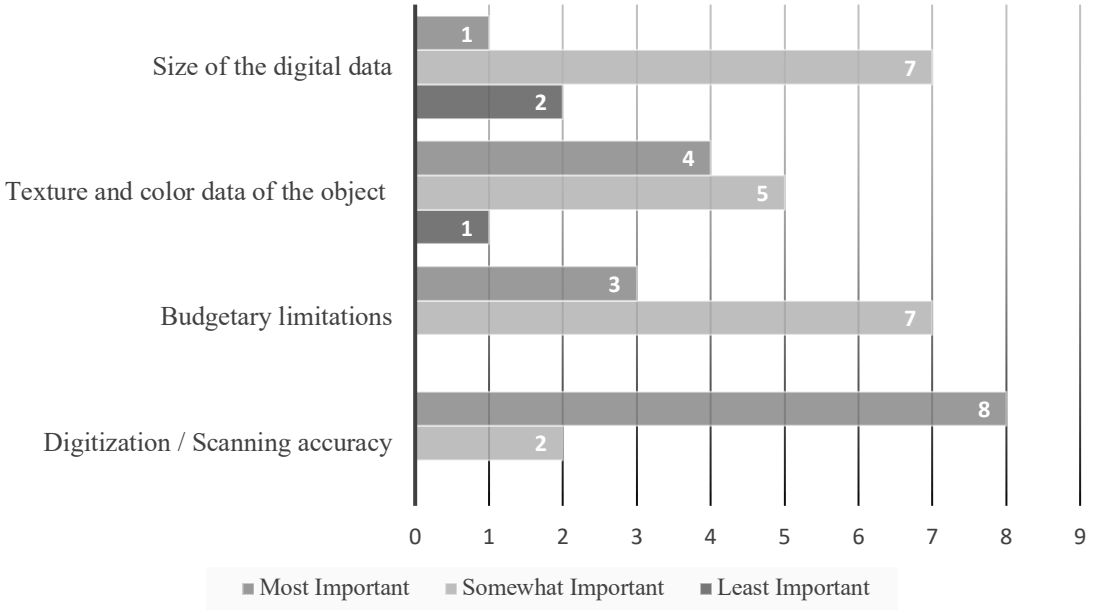
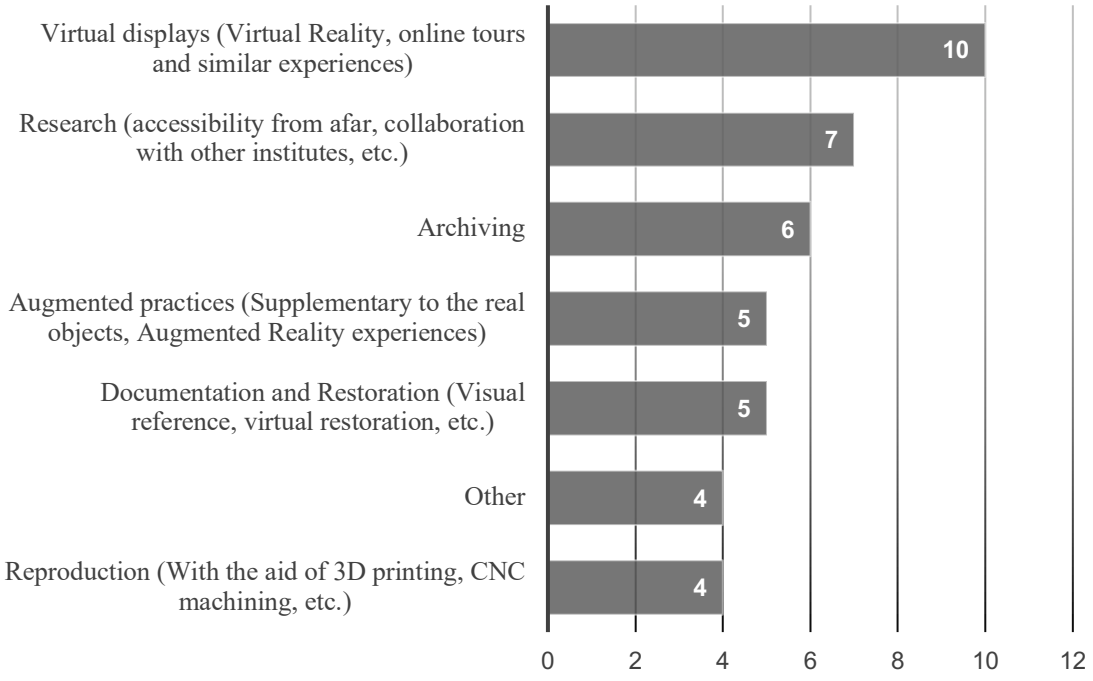


Figure 3.9. Bar Chart of Answers Given to Question #9



3 out of 10 participants wrote their own input as other use cases and all of them pointed to remixing 3D models to create new artworks. A response mentions Lucio Arese's award-winning short film as an example of creative reuse. Another one encourages all sorts of outcomes from the community. As a percentage, it may be a small number, but the consolidation of the answers, which were unbeknownst to each, is related to visitor experience. Making the visitor from a passive spectator to an active creator reinforces the idea of standardization around the experience since the importance shifts from the object to the experience itself.

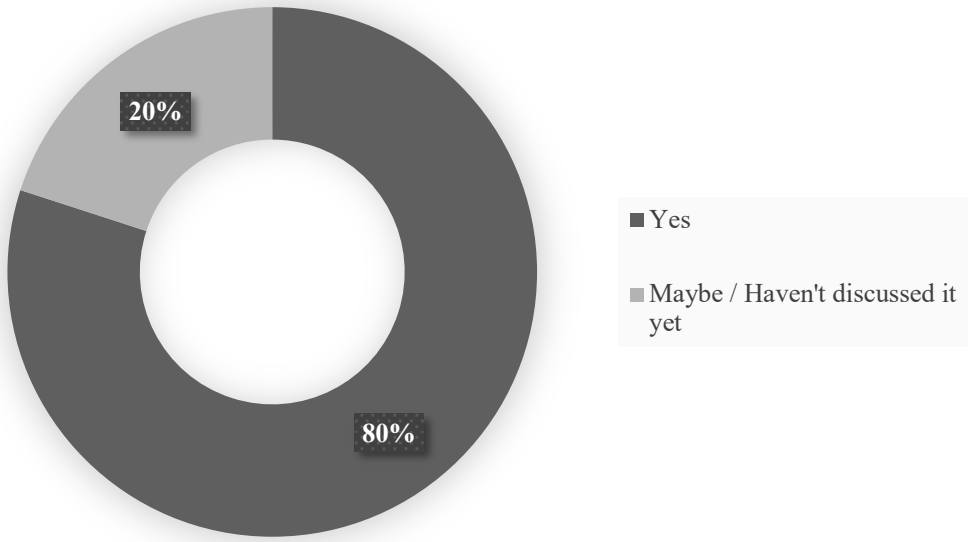
Budgetary limitations and the size of the digital data have been a concern for all the institutions, just with different priorities. The size of the data is irrelevant for just two institutions, which is interesting because one of them has one of the smallest collections, and the other has one of the largest collections. This may mean either the institution is heavily invested in 3D digitization, that digital storage space is plentiful, or the institution is at the beginning of its journey that modest storage options are affordable and sizable enough that it is not a concern yet. Other than the two institutions mentioned, consideration of the remaining 8 participants may point to a possible standardized filing system and its benefits due to file sizes (Figure 3.8.).

The answers on the importance of texture and color data may seem contradictory at first, due to one answer that says least important (Figure 3.8.). However, that answer belongs to the institution from the UK, which has more than 1000 objects in its collection. That institution is Scan The World, and their collection primarily consists of CH artifacts from around the world that have lost their paint layer. Therefore, there is no texture data to be captured and to be deemed important. For the other participants, since texture and color data is important in one way or another, a standardized way of capturing that data in a usable manner may be preferable. Strong use of Photogrammetry correlates to that.

The expansion of digital collections is a strong possibility for all institutions (Figure 3.10.). None of the participants selected *No* as an answer. 8 out of 10 participants declared that their collection is going to grow. The other two institutions, with less than 50 objects in their collections, are not certain. One of them is from Scotland, where their experience

was defined as a one-time project. The other institution is from Russia. For most of the participants a 3D digitized collection seems to be a viable investment and this highlights the need for standardization within its steps.

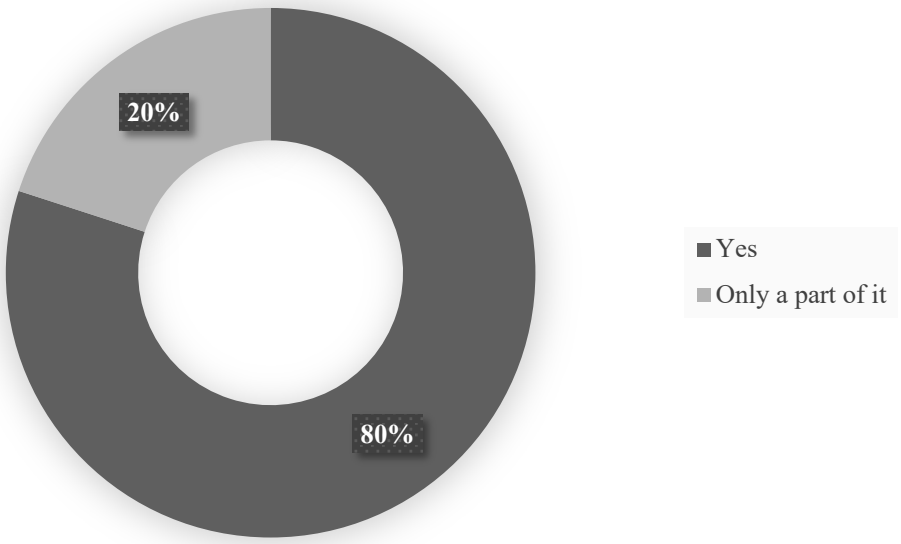
Figure 3.10. Pie Chart of Answers Given to Question #13



The institutions mostly share their collections freely with the public (Figure 3.11.). 2 out of them responded with *only a part of it* and these are Türkiye and Australia. In the institution from Türkiye's example, there are 30 objects on their website (Pera Museum, n.d.), however, their declared object count in the survey is between 100 to 500. Yet, they have no intention of creating a tier system for the rest of their collection to be accessible. As a matter of fact, only 3 institutions considered a tier system, in which a high-detail version is only accessible to some members with benefits and a more crude version is openly available. Two of them, the UK and Poland, have more than 1000 objects in their collection, and the other one is Spain. Sharing at least a part of the digitized collection seems to be a standardized action among institutions. Not all of the models, as well as all

of the versions may be available. However the act of giving access to the collections is a common practice.

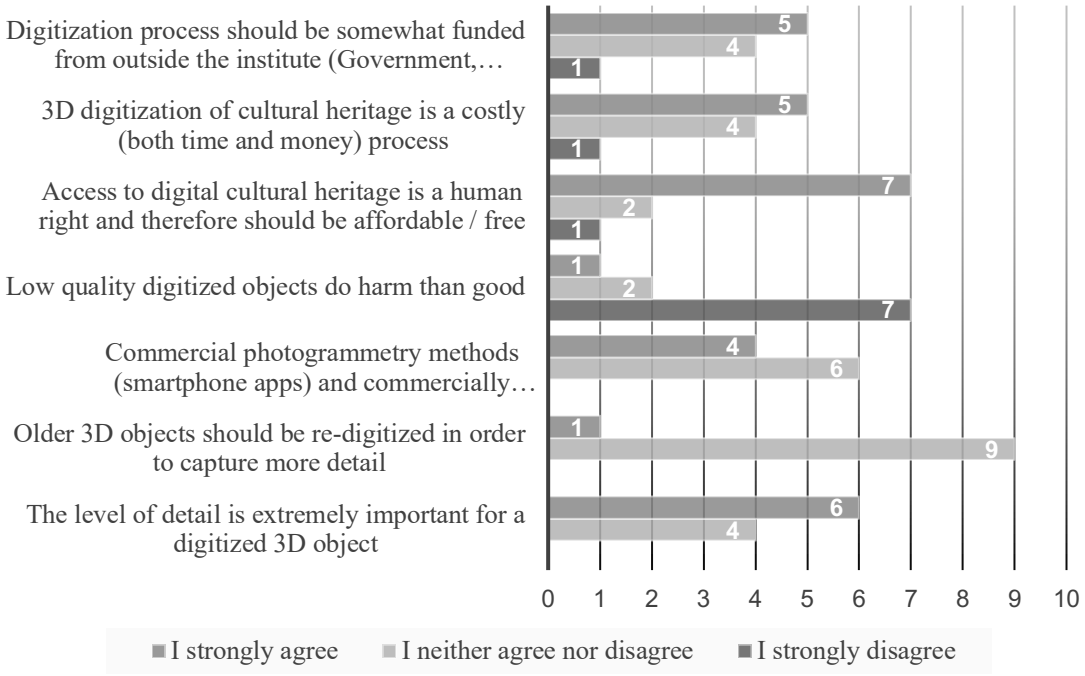
Figure 3.11. Pie Chart of Answers Given to Question #14



Unfortunately, there has not been a viable correlation between the tier system and the cost argument of 3D digitization. Rather, most of the participants believe that access to digital cultural heritage is a human right and therefore should be affordable / free. Only one participant declared that they strongly disagree with this notion, 7 institutions strongly agree and 2 institutions neither agree nor disagree (Figure 3.12.). In addition to that, only half of the participants said that digitization is a costly process, and the other half split between indifferent and disagreeing. However, one participant explained how they handle the highly detailed 2D digitized objects through the final input section. They don't offer a self download option since it is too heavy on their bandwidth. Instead, people need to contact them for the super high resolution of 2D files, and they charge a fee for handling those. There has not yet been a similar tier system implemented for 3D digitized objects in any of the institutions. There is at least a notion of standardization within the 2D

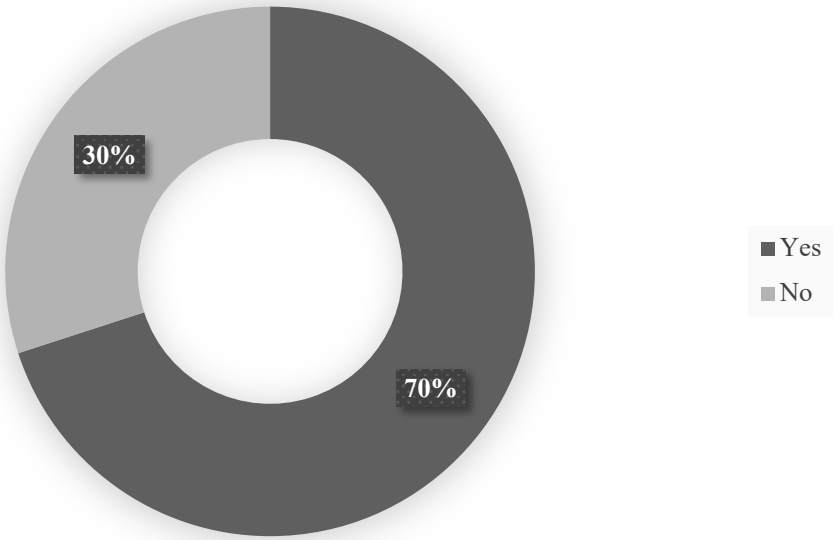
digitization processes, but for now, none for 3D digitization. Combining this notion with the previous one, meaning sharing only a fraction of the collection being held, there is not a clear standardized way of requesting access to the institutions either. Meaning, if someone requires a practical CH object for an educational purpose and the shared file is unsuitable for that purpose, a standardized channel of communication is non-existent.

Figure 3.12. Bar Chart of Answers Given to Question #20



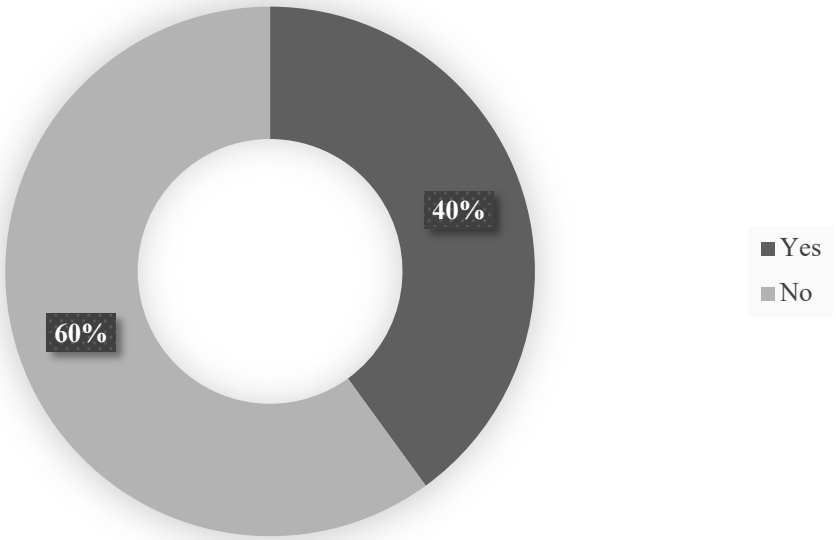
When it comes to digital obsolescence, collections with fewer objects are prone to be in danger. 7 out of 10 participants state that their instutitions tahe precoutions for digital obsolescence and the remaining 3 participants are also the ones with less than 50 objects in their collections (Figure 3.13).

Figure 3.13. Pie Chart of Answers Given to Question #17



However, there is a pattern of data preservation across institutions. On the following question, the participants were asked to give further detail about their methods. Most of them keep the raw data, and while doing that use open formats such as .OBJ or .PLY and open source solutions to ensure longevity; keeping multiple copies is another apparent solution. This means there is a standardization regarding digital obsolescence. However, the purpose of keeping multiple copies has a singular purpose for the institutions. When asked if they keep multiple versions of the digital objects for different purposes, 6 out of 10 said *No* (Figure 3.14). But 4 of those same institutions do keep multiple copies and versions, like raw data, for protective measures. This again shows that their interest is in the conservation of the data rather than creating a tier system or putting a paywall for the interested parties.

Figure 3.14. Pie Chart of Answers Given to Question #15



When asked about the photogrammetry done by the smartphones, 6 out of 10 participants remained impartial, while other institutions strongly agree with the technology. Also, 7 out of 10 participants strongly disagree that low-quality digitized objects do more harm than good (Figure 3.12.). These outcomes correlate with the idea of visitor experience rather than the micron-level details of the 3D digitized models. There is just one participant who strongly agrees with the harm argument. To give context, that participant is the 3D process supervisor, responsible for more than 1000 objects in the collection. It may be possible that instead of the museum experience, that participant's interests about the subject are purely technical and archival. The other participants who believe that low-quality scans do good are all the other titles that include curators, collection officers, and project managers. This branching, albeit high in ratio, indicates that use cases are indeed crucial for the perception of the digitized objects. If the objects need to be multipurpose, meaning for reproduction, archiving, research and be of utmost quality, then an institute may be critical about the commercial options being available. If it is the opposite and the concern is people experiencing CH objects, digitizing the objects themselves is more

important. There may not be a standardization within the perception of the techniques, but per use case basis, there seems to be a consensus and that is valuable.

Whether digitization should be funded, at least partially, with other than the institution itself is an agreeable solution for 5 of the participants (Figure 3.12.). There is no distinct correlation between this result and digitizing being a costly process, but there is no contradiction either. Some participants who agree with funding options also agree that digitizing is costly, while others neither agree nor disagree. However, all these participants who agree with the funding also have no digitization department in their institution. There may be mutually beneficial agreement between the service provider and the institution; an example is from Denmark, where the digitization is being made pro bono in return for receiving the digitized objects. Another example is Spain, which gets its digitization service from another department of the public administration. However, all these participants seem to acknowledge the cost of the process. Only one participant declared that it is not a costly process. The other 4 participants neither agree nor disagree with this statement.

3.3. Analysis of the Digital Collections

In addition to the survey, there have been examinations of digital collections which are open to the public. These are as follows:

- National Palace Museum - Taiwan (National Palace Museum, n.d.).
- Matsudo Museum - Japan (Matsudo Museum, 2022).
- Cleveland Museum of Art - USA (Sketchfab, 2019).
- The Royal Armoury (Livrustkammaren) - Sweden (The Royal Armoury, 2016).
- Global Digital Heritage (GDH) - USA (Global Digital Heritage and GDH-Afrika (@GlobalDigitalHeritage), 2017).

All of the collections are presented in Sketchfab, which confines them to the platform's standards. All the items within collections can be viewed on Sketchfab. The only difference is that the National Palace Museum prefers to showcase its objects on its

website, unlisting all of its objects in its Sketchfab profile (National Palace Museum, n.d.). And yet, if someone clicks on the Sketchfab logo on the website, which resides in the lower left of the display screen, it will lead them to their official Sketchfab page. Albeit all the items are unlisted, instead of public.

In terms of techniques, all of the digital collections use photogrammetry, with the inclusion of some post-processing being done within Instant Meshes, Meshlab, Blender or Zbrush. All of the institutions declare Photogrammetry in their profile pages. However, it may not mean that Photogrammetry is the only technique they use to digitize their collection. There is one written input from the survey and it says in their collection the most basic 3D representations are available on Sketchfab. This means for an institution, the overall collection and its digitized objects may be greater than their Sketchfab collection, as well as their techniques. As per object inspection, Global Digital Heritage also uses Laser Scanning as a fundamental scanning technique for their collection.

The quality of geometric data varies from collection to collection. The most noticeable difference comes with size and reflective objects. As for the size, Global Digital Heritage has monuments, buildings, and archeological structures within its collections as well as smaller objects. Their buildings are, although high on polygon count, relatively low quality. It needs to be reminded again that this version of the digitized object may not be the only one, considering several institutions within the survey declared that they have been keeping multiple versions of the objects. Several attempts to contact Global Digital Heritage for this research have been unsuccessful, therefore, there is no concrete information about the multiple copies of their collection.

All of the 3D models within the collections can be viewed with current smartphones, which is a standard in itself. This is with the help of the Sketchfab system, since all of these collections are optimized for the platform when uploaded. 3 out of 5 institutions declare that they use RealityCapture, albeit in different places. Global Digital Heritage usually gives this information in their object descriptions, as well as in The Royal Armoury. Cleveland Museum of Arts often works with an individual, Dale Utt, who has

his own Sketchfab profile, and although they don't include this information in their object description, Dale Utt does (Dale Utt, 2019).

When it comes to licensing, the National Palace Museum is highly restrictive. The institution doesn't give any kind of Creative Commons (CC) license to their objects, nor a chance to download them. On the other side of the spectrum, the Cleveland Museum of Arts has CC 1.0 Universal Public Domain. Which means they forego every right they have over the digitized objects. The public is free to do whatever they want. Global Heritage and The Royal Armoury has CC Attribution 4.0 International License. This license means the user, as long as gives appropriate credit to the creator, can copy and redistribute the material freely, also even commercially. The user can also remix, transform and build upon the material. Matsudo Museum has a similar license, CC Attribution-Sharealike 4.0 International. The only difference is that if the object is remixed, transformed, or built upon, it must be shared under the same license as the original material. This means all the objects with the licensing Attribution or Public Domain can be downloaded with the file formats provided by the platform.

Regarding the survey participants and their free-to-access web collections, there are similar approaches as well. Scan The World, with its more than 12,000 objects, has its own licensing system through MyMiniFactory. Their objects are free to remix, share, manufacture, non-commercial and required to credit the author. Pera Museum and Australian Museum are free to access, but there is no public way to download any objects; therefore, they are devoid of any kind of CC-like licenses. SMK Staten Museum is working with Scan The World for the digitization process, therefore their licensing system applies to their collection as well. The Hunt Museum, Darwin Museum, and Scottish Maritime Museum use Sketchfab as their platform, and while the first two institutions license the objects under CC Attribution 4.0 International, the last one uses CC 1.0 Universal Public Domain. Malopolska Cultural Department and Assembly of Museums has their Sketchfab profile as Virtual Museums of Małopolska and although it doesn't have all of the collection that the department has, all of the objects provided are under CC 1.0 Universal Public Domain license. Museu Nacional Arqueològic de Tarragona is working with Global Digital Heritage for their collection to be digitized. Therefore, the

licensing is the same as that of GDH. The Smithsonian Museum has one of the largest collections and there is not just one licensing for all the objects. If the object is a historical scan like a spacesuit or a prom dress from the 1980s, there are specific conditions that apply. However, if the object is an archeological find, most of the time, it is in the Public Domain license. In the end, only 2 out of 10 participants, Türkiye and Australia, restrict their 3D objects to be downloaded through standardized ways. 8 out of 10 institutions give their virtual visitors options to download and be active participants with the 3D objects.

Regarding viewer experience, the National Palace Museum and The Royal Armoury take advantage of the existing systems. Through annotations, both of these institutions enrich their objects within the Sketchfab platform. The user can experience them in order, or they can choose randomly while rotating the object in 3D space. At the time of writing, 70 objects are in the National Palace Museum collection, and all of them have multiple annotations. There are 13 objects within the Royal Armoury Museum and 4 objects are with no or faulty annotations. Cleveland Museum of Arts has a different approach. Instead of annotations, the institution has animated objects within their collection. Whether an assembly of statues (Pair of Guardian Figures, 2022) or an opening mechanism of a container (Sutra Container, 2022), there are repeatable animations within the collection. Survey participant The Hunt Museum has one object with annotations within their Sketchfab collection, however, it is not a continuous trend. The Smithsonian Museum has its own platform and through that, it has an annotation system, which incorporates questions, hyperlinks to other web pages and the option to showcase different layers of 3D objects like the internal mechanisms of a spacesuit.

For almost all the survey participants, the active viewer experience is a strong priority. Although not every object and every collection has annotations, at least leaving the orientation of the object to the viewer, as well as whole 360 degrees digitization makes the participant in every way, active.

3.4. Preliminary Conclusion of Survey Analysis

In accordance with grounded theory, selective coding was established and the data analysis was done according to that coding. As mentioned in the Selective Coding section, the central category is *Use case appropriate accuracy*. This statement comes from understanding the data both from the survey and the examinations. When it comes to defining the place of standardization, this notion seems to be the central factor among the institutions that have been examined.

At first, scanning accuracy seemed to be a defining factor for standardization. With many scanning techniques and advancing technologies, quality of the 3D data is a primary concern (Quintero & Eppich, 2016). Also when it comes to the originality of the object, it must represent its origin as closely as possible since it is an authenticity requirement by UNESCO (UNESCO, 2003a). However, survey and digital collection examinations showed that the importance usually relies on the overall object accuracy rather than every micron-level geometric detail. Landscape monuments and buildings are almost like mushy blobs without their textures. To give proper context, they cover a substantial surface area with optimized geometric data, therefore, the loss of detail in their geometric data can be understandable. However, the same loss of detail can be found in numerous digital objects, from a broken column to a binocular from the 1800s, within the research's sources as well. The texture data, which is tied to the geometric data, is what makes the objects resemble their original form, even though they are inadequate for any other use case rather than virtual displays. Every object has its texture, and it has information about the origin of the original. With the assistance of standardized platforms, the objects have selectable layers with metadata; wireframes, MatCap, and annotations where presented. Even though they lack details that are essential for reproduction, all the digital collections serve their purpose and they meet their bare minimum in terms of a standardized collection.

Another deviation from open coding is the actual size of the digitized collection versus the displayed collection and its interpretation. According to the survey, even when an institution presents less than 50 objects in its free digital collection, it may very well have

more than 100 objects in its actual collection. There have been economical concerns when it comes to physical attendance versus digital collections (Elias, 2019) and this discrepancy may be explained by this notion. In addition to that, multiple copies are being stored for both safety and different use cases. Up until the survey, the overall idea of this research was to consider all the available collections as the whole collection. And yet, with the answers given by the participants, this notion changed drastically. Through that understanding, the requirements per collection that serves a use case, are born. Instead of keeping a singular version and using that object for every use case possible, the collections seem to be assembled based on the necessities. Through these necessities, appropriate and efficient solutions are found and therefore a basis for standardization as well. Open standards and file formats are a necessity when a collection needs to outlive the current technological operating systems. A robust and established metadata protocol is a necessity for a large collection which is also navigable. A 3D object needs to have sufficient detail in its geometric data in order to be reproducible with automated techniques like 3D printing or CNC machining. This reinforces the heavy criticism around the Arc of Palmyra since the model had less detail to be sufficiently reproduced with automated techniques (Khunti, 2018). Every use case has its own accuracy requirement, however, there is no one standardization that can be applied to all of these use cases. This is the basis of the central category that defines the theory about the standardization.

As a step by step example, for virtual displays, the preferred digitization technique seems to be Photogrammetry. The geometric and texture data are primarily captured based on the requirements of that use case. Therefore, when choosing a display platform, in this research's example Sketchfab, all that preliminary technical standardization comes with that. According to the descriptions that have been gathered from the digital collections, RealityCapture is a prominent application to create a 3D model by combining photographs. Its usage is no coincidence because both Sketchfab and RealityCapture belong to the same parent company. It isn't to say that in order to upload a digitized object to Sketchfab, one must use RealityCapture, however, there is an ease of integration for these two systems. There is also the issue of licensing if an institution decides to give the option to download referred objects. This is the territory of Creative Commons, a

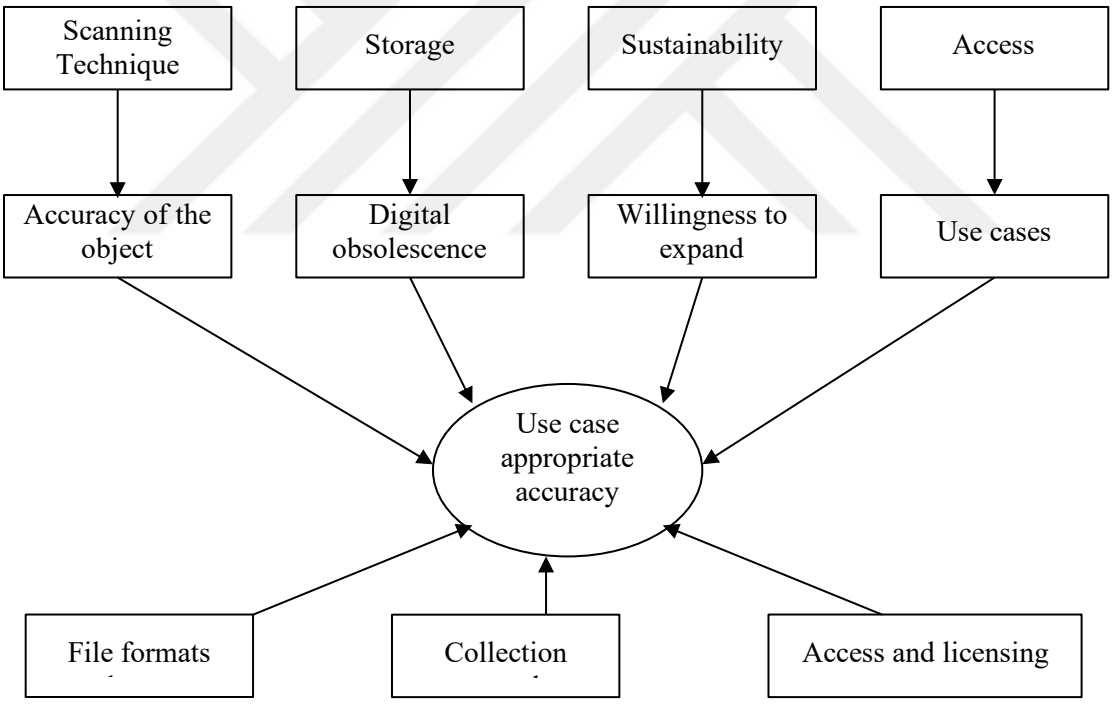
relatively easy-to-understand standard that has helped people since 2001(2023 Annual Report, n.d.). However, if an institution refuses to allow downloads of their 3D model data while allowing a virtual display, there is no Creative Commons standard to speak of. It is decisively irrelevant.

One use case scenario, with its own requirements, is prioritized among the others. Since digitization is a lengthy process, when institutions begin their journey, they tend to choose that use case above all: Virtual Displays. Meaning, the primary concern of institutions is to connect the visitors with the CH objects that are within their physical collection through digital means. When considering the place of photography within modern museology, there was one clear goal: to elevate society through the morally beneficial influence of great art (Walsh, 2007). After almost 200 years, the same goal still applies to digital collections. Similar to blurry photographs and before that, plaster molds, the purpose is to connect the public with the resemblance of the original objects and broaden their perspectives. 3D digitization also adds to that, remixing lets the visitors be active participants. Commercially available Photogrammetry techniques with smartphones allow visitors to scan the objects themselves, making them engaged with the objects (Elias, 2019). Although the copy is not highly detailed for reproduction, through exposure and experience it increases the value of the original object (Walsh, 2007). This practice may also be beneficial for the institution, like Rijksmuseum and their annual design challenge gathering more visitors than regular (Rühse, 2017). When visiting the online collections of the institutions, for almost all of them, there are options to download 3D objects for personal use. In order for this download option to work, the file formats should be widely used and open such as .OBJ, .STL, .PLY, .USD; downloadable through an understandable platform like Sketchfab, MyMiniFactory; with a clearly defined licensing like Creative Commons. When it comes to protection against digital obsolescence, these practices also create safety through conservation (Silver, 2016).

In terms of standardization, the idea of elevating society seems to be the primary force, just morphing into different needs among the use cases. To give another example; for educational purposes a 3D object of a mechanical system may be scaled down to be better explained (Neumüller et al., 2014). This may require a little more geometric accuracy

than a mere virtual display object, since tolerances between the pieces that move mechanically need to be precise enough to work. The texture data is also redundant, since through reproduction digital texture is useless. This use case, with its scanning technique and base precision standardization is still committed to the same original purpose, to elevate society. Every use case appropriate accuracy demand, whether it is texture geometric, metadata, licensing or file format originates from the same purpose. The idea of standardization is tied only to this notion, then regains its shape differently per use case (Figure 3.15.).

Figure 3.15. Complete Category Diagram of the Place of Standardization



And yet, elevating society is not the central category, because it is not the basis for standardization. It is the primary force that every use case is based upon. The need to digitize, to archive, to display, to share, to let people remix born from this idea. However, standardization is a secondary step to this process and it is still tied to use cases regardless of the originating purpose.

The importance of raw data, regardless of the use case, is apparent. The notion of raw data, whether it is a point cloud data from a laser scanner or a series of photographs in order to be used in a photogrammetry session, and its safety may be a standardization topic all on itself. Even the safety of final file formats may not be protected through different standardization topics, raw data and its preservation seems crucial. Since more digital file formats and varied degree of detail can be produced from a single raw data set.

CONCLUSION

Digitization of cultural heritage has spun across multiple decades, however 3D digitization itself is considered relatively new. Due to its versatility, 3D digitization brings different use cases, both for experiencing and protecting the objects within CH collections. It is possible to archive, preserve, restore, even reconstruct and remix the existing CH object and create new contexts and attach new life experiences to them. The digitization itself has foundations in industrial applications, therefore, the advancements in the digital imaging technique have a way of finding themselves in the cultural heritage institutions. This opportunity brings incredible options, whether to digitize the objects in their full detail or quickly digitize them for fast-use scenarios. However, with this kind of variety of techniques comes the difficulty of defining what a technically adequate digital CH object is.

This research asked the question of standardization and its place within 3D digitization, precisely for that notion. The beginning of the research through literature analysis shows that in the technical sense, the speed of advancing technologies and the lack of oversight may be a threat to the collections. Preservation of cultural heritage is meant to communicate between the past and the present, however due to technological advancements, it becomes more complex and more difficult due to lack of standardization (Quintero & Eppich, 2016). The same concern is apparent in the reproduction of CH objects, since dimensional accuracy seems to be highly important in order to reproduce objects, use the digital copies to restore existing artifacts, or preserve a copy of a physical object through digital means as long as possible. On the digital side, digital obsolescence is a prominent problem that may result in losing archival files through avoidable means. These points are the cornerstones of the literature analysis, mostly revolving around technical proficiency and standardization.

In order to correlate these findings with real-world practices, a survey was created and sent out to the institutions that agreed to participate. In addition to that, websites and

accessible collections of the participant institutions were also examined, with digital-only 5 more evaluations added to the data pool. Although there have been several questions about the technical side of digitization, the survey also includes questions about different use cases, accessibility, budgetary limitations and even governmental interference. The aim is to paint a broader picture than just the technical standardization and its importance, while trying to create a network of outcomes that can be interpreted via grounded theory.

The hypothesis that was constructed through literature analysis began to morph with the survey, especially on the idea of technical standardization. It was believed that high-detail digitization is important in order to create an acceptable collection, which was supported by the literature itself. However, through the survey, it was revealed that every use case tends to have its own necessary standards for it to be acceptable. These use cases have their own needs and convenient ways of digitization based on the requirements, and specifically on the virtual displays use case even if the objects may lack geometric data that makes them suitable for reproduction, the collections they belong to still serve their purpose. The survey also revealed that not every public collection is the one and only version of the digital objects, based on the comparison of public digital collections versus declared collection sizes. These outcomes are interpreted in a way that not one standard regarding the digitization is possible, or even required to attain since use cases and their needs differ.

After the technical assessment, another evaluation about the standardization of collections was done regarding how they are being shared with the public. Strongly based on the virtual displays use case, almost all of the collections include textures and relatively low geometric detail that somewhat retain the resemblance of the objects and are easy to view in low-performance computers and smart devices at the same time. For most of the institutions, a way of downloading and remixing these objects also has a chance to create a connection between the CH objects and the viewer, making them active participants, whereas physical museum attendants usually be defined as visitors and the experience is generally passive. Converting the passive to the active with the help of remixing or controlling the narrative of the digital object through virtual display technologies, with the help of ease of access, seems to have a goal of elevating the taste of society through

great art. Instead of defining a standard for a technical aspect of the digitization process, the standard itself seems to be achieved through intent and using any relevant and convenient technique possible. For a reproductive manner, that standard includes a highly detailed geometric model, whereas for a virtual display the texture is a necessity and therefore defined as a standard. Yet, these different use cases may not intersect, since a highly detailed geometric model is an intensive work for a computer and it reduces the accessibility aspect of the CH object and may even be counterproductive.

Through the survey, it has also been revealed that institutions which are serious about digital obsolescence, primarily share similar techniques to mitigate the danger. Open source file formats, clearly defined licensing agreements, and the storage of multiple copies of digital objects seem to be the standardized way of ensuring the survival of collections. Although there is not a properly named standardization for this matter, there seems to be a unified perception.

It was imperative to include participants around the world in order to understand if geological, political or economical differences may impact the approach to 3D digitization of CH objects. Due to outcomes of this research and regarding the participants of it, it is safe to say that there is no arguable difference between institutions based on their location. The importance of digitization indeed has importance on different parts of the world, as the example of the long lost structures in Syria had already been given. However there have not been a viable candidate from that region to include in this research. Therefore a conclusion cannot be made in that regard.

In terms of collection size, whether a museum administration is public or private is not relevant. One of the largest collections belongs to The Smithsonian Instutition, and the other one belongs to Malopolska Institute of Culture. When it comes to used technologies, different countries still prefer the same techniques that suits their needs, therefore reinforcing the idea of *use appropriate accuracy*. Since technology is not in the hands of the few and know-how can travel vast distances, different regional and/or international institutions make the same conclusions about their approaches to 3D digitization. The only found difference, however may that be a bit of a stretch, is regarding approachability

and communication. Western institutions, although not every email that was sent had been replied, are more approachable. On the other hand the institutions in the Far Eastern region limit their approachability through language barriers, absence of public email addresses, even limiting messaging systems on their websites to the citizens with valid identification numbers. The reason, that this difference may be a bit of a stretch, is some Western institutions have also left the attempts of communication unanswered. Although more approachable the Western institutions were, in the end the outcome was the same.

There have been limitations for this research, which have already been listed in the Chapter 1. However, after the completion of the analysis, some additions need to be made that a future researcher may find useful.

Firstly, even though singular participants were requested from the institutions, a duo may be more efficient in discerning employees' approaches. Most of the participants who have answered the survey are in administrative positions and/or people who are related to the curation of the collections. Only one person has a label strongly tied to the technical side, and the answer of that particular person is highly different in some areas which was stated in the analysis of this research. Based on that difference, a two-person team of participants, one of them is technical and the other one administrative, from every institution would have been more enlightening. With every email, the option to have an interview with the people who are responsible for the collections were given and yet there were no positive responses.

Secondly, reaching more countries, especially around the world, which were not represented, may enrich the outcome of the research. Although it was tried repeatedly through different communication channels, it was not possible to reach some institutions. A physical visit with the proper credentials may help instead of reaching through the internet, unfortunately, it somewhat goes against the nature of the whole research in a sense, which lays out the positive outcomes of transferring digital objects to be reproduced all around the world and the convenience of it.

Also, remixing as a culture may be investigated further, both legally and in a participatory manner. There are remix sections on some websites that house collections like

Thingiverse or MyMiniFactory. Those sections show the original file, as an additional information tab of the remixed versions. This means a person can follow the file through its first iteration, clicking through remix after remix. That kind of breadcrumb is valuable in order not to lose track of the original object. Whether that kind of active participation and its trail is available for the institutions or not and if that trail is effective, may possibly be a whole section of another research.

Finally, there have been emerging technologies even while this research was coming together. An example is Gaussian Splatting, which creates a volume rendering of a point cloud data without turning it into geometric data. This means, without creating processor intensive geometric data files, through proper rendering engines a highly dense and detailed point cloud data may be recreated. The problem is, as of writing this research there were no commercially available and easy-to-use volume engines that can render gaussian splatting properly. Therefore, even with its powerful implications for the future of archeological sites and virtual display techniques, currently it is not possible to gather literature and/or practical use data on the subject.

All in all, a standardized way of technology, with a fast-moving industry like 3D digitization, may not be possible at the moment. However, this doesn't mean the underlying intent or the overall process of digitization is exempt from the idea of standardization. Metadata usage or visitor attendance rules are standardized in their own way and although these are not the main areas of this research, it accompanies the fact that all these standards are used to create institutions that crave to elevate the taste of the general public through great art and historical accumulation.

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APPENDICES

Appendix A. Result of the Evaluation by the Ethics Committee

Result of the Evaluation by the Ethics Committee is available in the printed version of this dissertation.

Appendix B. Online Survey Responses

3D Digitization of Cultural Heritage Artifacts

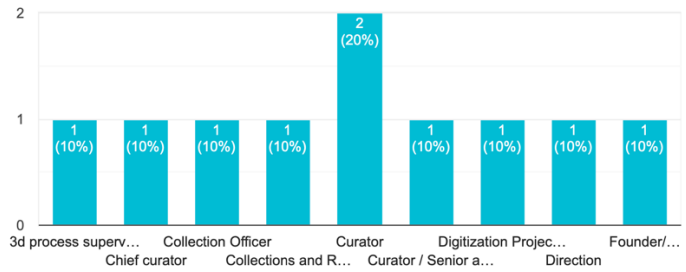
10 responses

Publish analytics

What is your position within the institute?

Copy

10 responses



Which country your institute operates on?

10 responses

Australia

UK

United Kingdom (Scotland)

USA

Russia

Spain

Turkey

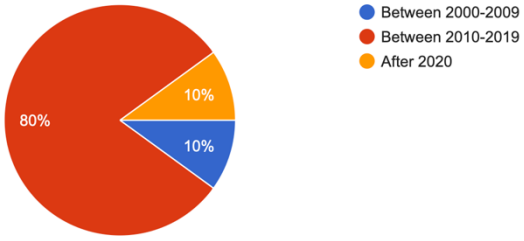
Ireland

Denmark

Poland

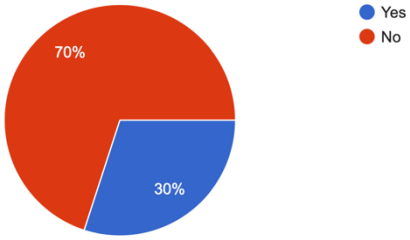
When did your institute begin 3D digitizing its collections? Copy

10 responses



Is there a 3D digitization department within the institute? Copy

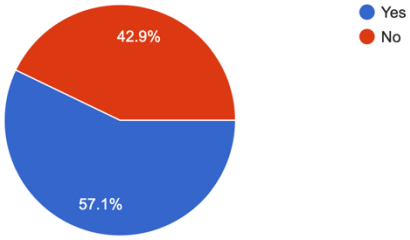
10 responses



Digitization Partners

Is there a recurring partner for the 3D digitization process? Copy

7 responses



If "Yes", what makes your institute choose the same company as a partner?

4 responses

Our partner is another department of the public administration

We started to 3D digitize the Kütahya Tiles and Ceramics Collection of the Foundation as part of an artistic project in collaboration with the artist collective Oddviz. We then worked with them to digitize the Anatolian Weights and Measures Collection for archival purposes.

It is not a company but we employ an technician on a consultancy basis to digitise and publish.

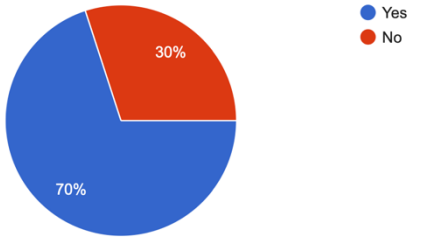
It's a partnership with the NGO Scan The World who scans works in our collection pro bono, as a mutually beneficial exchange of data and knowhow - more info about the partnership in this article https://www.myminifactory.com/blog/smk-open-new-online-collection-hosts-scan-the-world-models-in-collaboration-with-smk

Details of Digitized Collection

Is there a person managing the 3D scanning and digitization process within the institute whether it is being outsourced or not (a designated supervisor)?

Copy

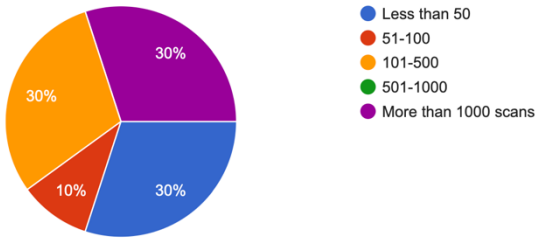
10 responses



How many objects are there in the digitized collection of the institute?

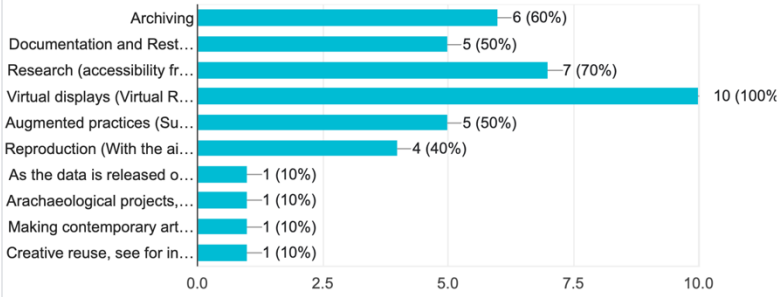
Copy

10 responses

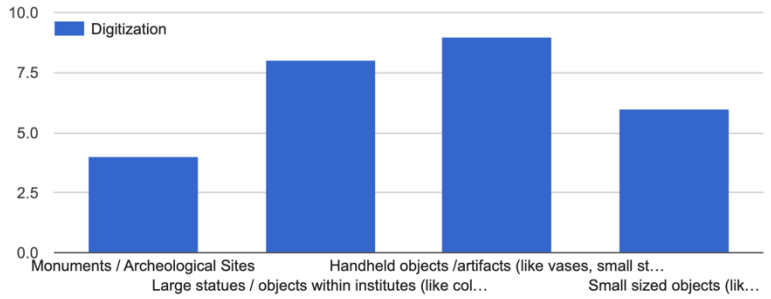


What are the use-case scenarios for the digitized collection? Copy

10 responses

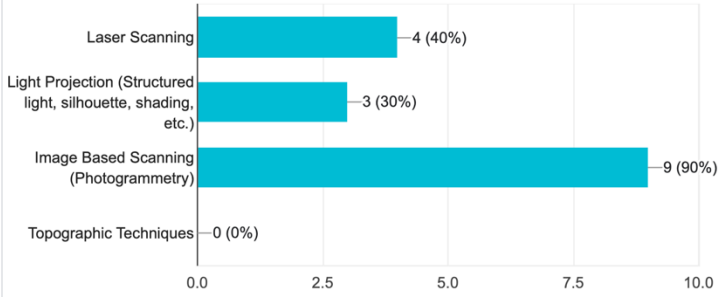


What does your institute focus on digitizing? You can select more than one topic. Copy



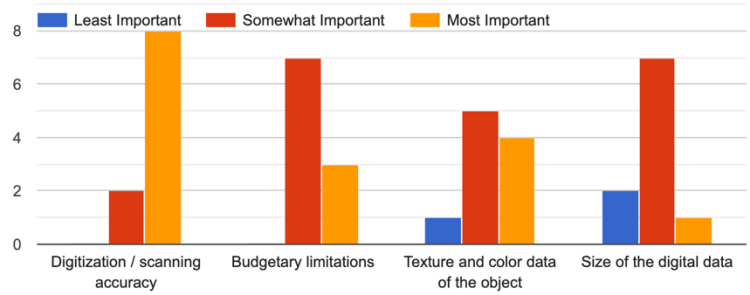
Which methods are preferred for the 3D digitization within your institute? Copy

10 responses



What aspects of digitized objects are relatively important to you?

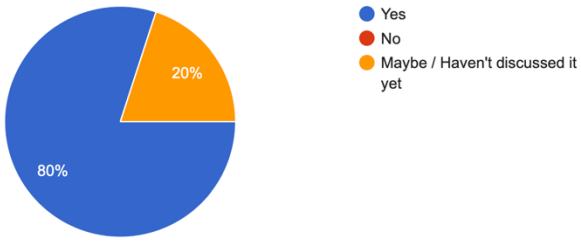
Copy



Is your institute still committed to expanding its digital collection?

Copy

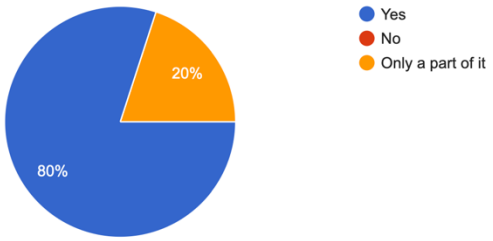
10 responses



Is your digital collection openly accessible (free to access) through online channels?

Copy

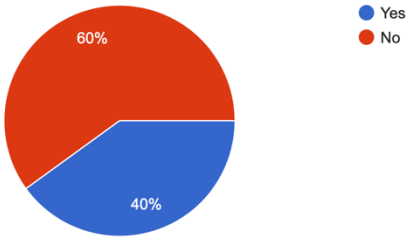
10 responses



Do you keep multiple versions of the digital objects, for example one for free access and the other for educational / research purposes?

Copy

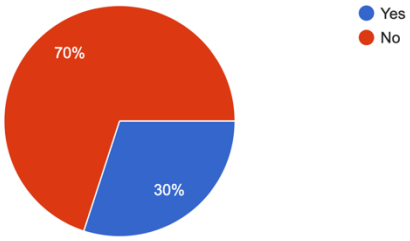
10 responses



Have you considered a tier system for accessing different levels of detailed 3D objects for different fees / credentials?

Copy

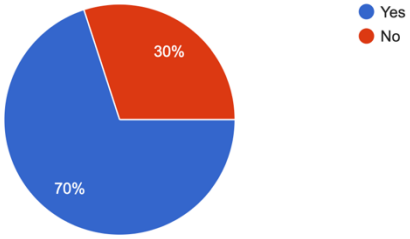
10 responses



Does your institute take precautions for the *Digital obsolescence*?

Copy

10 responses



If "Yes", what kind of precautions are being taken within the institute?

7 responses

Keeping the raw data, as well as exporting the files into a range of formats. The OBJ format is currently the most stable.

Keep multiple copies across different mediums. Backup kept digitally.

archiving raw data, investing in open source solutions

We are working on this issue in parallel with the deployment of the projects, but we do not have a definitive solution yet.

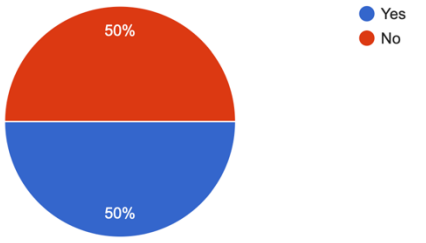
Making multiple copies

This is happening in dialogue with Scan The World as they have and host the raw 3D models.

Storage is made with open formats (i.e.: OBJ, PLY) on multiple locations, most basic 3d representations are available on Sketchfab

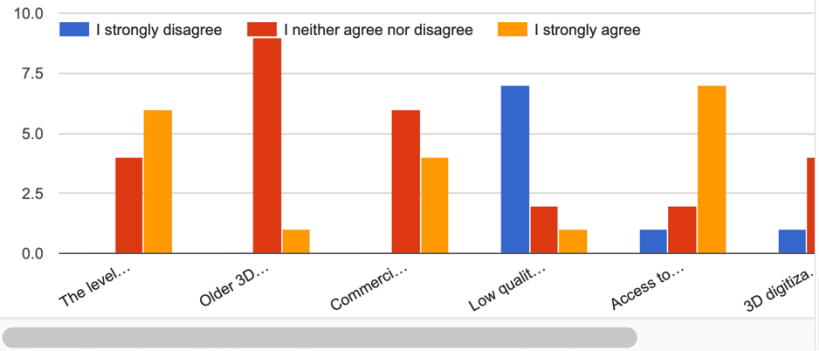
Do you keep updating your existing digitized 3D objects according to the technical advancements? Copy

10 responses



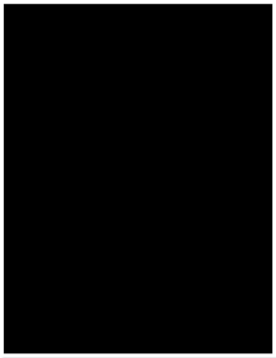
Final Section

From agreeing to disagreeing, please select accordingly. Copy



If you don't mind us contacting you in the future, please kindly share your email address.

6 responses



Is there anything you want to add regarding 3D digitization of cultural heritage in response to any questions we have asked?

4 responses

Aspects such as detail or quality depend on the objective of the documentation

I replied NO to the last question on the previous page because we haven't needed to update the digital objects yet. If the technology advances and we are not able to use these models with updated versions of software, we would take necessary actions in the future.

Re: the question "Do you keep multiple versions of the digital objects, for example one for free access and the other for educational / research purposes?" - I replied 'No' because you may download images/scans free of charge for all purposes (of works in the public domain). However, we don't offer original/highest resolution files for self download because it's too heavy on our bandwidth. So people need to contact us for the super high resolution of 2D files, and we charge a fee for handling those. I don't know if you can get the raw 3D files from Scan The World and if it costs anything.

no

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