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## Cultural Heritage Digitization and Valorization with 3D Imaging Technology

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### **Abstract:**

One key aspect of digitizing and valuing cultural heritage is two-dimensional imaging. This technique has facilitated the recording of archaeological sites and artworks, providing scholars and other interested parties with access to crucial data. The development of three-dimensional technologies has opened up new possibilities for heritage representation, including increased realism and accuracy. Significant advancements have been made in three-dimensional scanning technology, and laser scanners can now capture minor details of artifacts, enabling to creation of copies that are exact replicas of the original in terms of size, shape, color, and texture. In addition to documenting, this procedure makes it possible to virtually rebuild archaeological sites.

**Keywords:** 3D Imaging Technology, Digitization, Urban Heritage, Cultural Heritage Preservation

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## 1. INTRODUCTION

Cultural heritage encompasses both tangible and intangible elements that reflect the history and identity of different people. This includes historical monuments, artefacts, traditions, arts, languages, social customs, and folk tales. Cultural heritage is a vital part of human identity, illustrating the history and traditions of societies. Traditional imaging techniques, such as 2D imaging, have been effective tools in documenting this heritage, but they have not been sufficient to meet the growing need for accurate documentation and preservation. With the advent of 3D imaging technologies, a new era has begun in the digitization of cultural heritage.

Accordingly, because 3D imaging technology delivers capabilities that 2D imaging does not, it is a revolution in the field of cultural heritage preservation. Reconstructing virtual replicas of artifacts is made possible by the use of 3D laser scanners, which produce precise models with dimensional details. This not only increases the accuracy of documentation but also allows users to interact with heritage in new ways, such as virtual tours of archaeological sites.

3D imaging technology has been used in many global projects, ranging from major museums to remote archaeological sites. For example, this technology is used to document historical monuments, which helps in their restoration and protection from corrosion. Digital models also facilitate academic research, as researchers can study artefacts remotely. Despite the great benefits, 3D imaging technology faces several challenges. Although the applications used in 3D scanning are easy, this does not mean that it can be used in all museums and archaeological sites, as 3D data for museums and artefacts can be largely inconsistent, including differences in geometric

accuracy and colour. The most important challenge in documenting cultural heritage through 3D imaging is the lack of sufficient knowledge of the documentation process.

Accordingly, 3D imaging technology signifies a vital progression in the preservation of cultural heritage, safeguarding its accessibility for future generations. By integrating this technology with other advancements, we can amplify our initiatives to protect and engage with cultural identity. Although this approach necessitates investment in both technology and training, the potential benefits for preserving cultural heritage are considerable. Therefore, we put forth the following problem statement: How can cultural heritage be digitized and valued by applying 3D imaging technology?

### **1.2 Study objectives:**

1. Exploring the 3D imaging technology development stages and how it is used to document cultural heritage.
2. Studying how 3D scanning is used to preserve artefacts and historical sites.
3. Understand the role of 3D scanning in maintaining cultural heritage and protecting it from deterioration.
4. Raise awareness of the importance of digitization in the preservation of cultural heritage.
5. Examine the technological and logistical challenges of 3D scanning in the historic domain.
6. Examine the methods and tools used in 3D scanning, including photography and lasers.
7. Providing recommendations for improving the methods used in digitizing cultural heritage.

### **1.3 Methodology and Tools:**

The historical method was employed, which is a research method that aims to study events and phenomena by analyzing various historical sources, which helps in understanding the development of ideas and technologies over time through:

- Examining the evolution of 3D imaging technologies from their inception to their current uses in the field of cultural heritage in order to analyze their temporal evolution.
- Examining the impact of cultural and historical contexts on the adoption of these technologies in documenting heritage. Studying how they contributed to shaping cultural policies.
- Using historical sources by taking advantage of documents, articles, and previous research to understand how technological developments affect the preservation of cultural heritage.

### **1.4 Study Tools:**

- Primary sources: historical documents, old photos, archaeological evidence.
- Secondary sources: previous studies and research on 3D imaging technologies and their uses in heritage.

### **1.5 Study Concepts:**

#### **A. Digitization of cultural heritage:**

It involves transforming historical and cultural data into a digital format. It enables the use of contemporary technology for information processing, storage, and display. It includes the use of tools such as 3D scanning, photography, and digital recordings to document artefacts and sites.

#### **B. Valuing cultural heritage:**

It entails evaluating the historical, cultural, social, and economic significance of cultural heritage in order to raise awareness of its worth. This includes conducting research studies and surveys to establish the cultural and historical significance of

items and sites. It also aids in the creation of plans to raise this value.

### **C. 3D imaging technology:**

It represents a set of technologies used to create 3D models of objects or sites by capturing visual data. It includes the use of equipment such as laser scanners or photography programs to convert real dimensions into a 3D digital model that can be used in study or display.

#### **2.The development of 3D imaging in cultural heritage:**

Because 3D imaging has a direct relationship with computer technology, its historical development in the field of cultural heritage closely reflects improvements in other technological fields. The evolution of computer processing power has been essential for the progress of 3D imaging. Transistors that could be incorporated into computer chips were first introduced in the 1950s, marking the start of the adventure. Despite their compact size, the earliest transistors lacked the power that modern ones do. The invention of integrated circuits in the early 1960s was a qualitative leap, as more transistors could be installed on a single chip, which meant accommodating more processing power.<sup>1</sup>

Over the years, research has concentrated on making circuits and chips smaller. Since 3D imaging equipment and software primarily rely on a computer's processing power, the rapid technological development that started in 1975 and has continued at an accelerated pace for the past 50 years<sup>2</sup> has spurred advancements in the industry. As these capabilities have

improved, the features of the devices and programs used in 3D imaging increased. A 3D scanner captures data, but it is the computer to make it comprehensible and processes it. After then, the computer's central processing unit (CPU) or graphics processing unit (GPU) makes the computations required to decipher the scanned data<sup>3</sup>. From 1995 to 2005, Experiments in 3D imaging for cultural heritage have been ongoing for about twenty years. One of the earliest examples is the Digital Michelangelo Project, which began in 1998. While there were smaller projects around the same time, the Michelangelo Project spanned one year and aimed to scan as many of Michelangelo's sculptures as possible. Ultimately, the project successfully scanned ten statues. The objective was to capture the objects with a high enough resolution to ensure they met the 3D quality standards of the time. A triangulation-based scanner was employed, and the results were quite impressive. The project achieved its goal of obtaining high-resolution scans of the statues.<sup>4</sup>

An old statue was scanned in 2002 by Fausto Bernardini and his colleagues at the IBM Research Center. Compared to Michelangelo's project, a new technology was employed. The scanner was also photometric, but it used a stereo system and structured light rather than laser triangulation to take several pictures from a three-dimensional grid. The project's outcomes were extremely positive<sup>5</sup>. From 2006 to 2016, the same previous methods were still in use, but they improved in terms of quality, speed and the ability to reduce costs. The structured light method was used in the Museum of Cultural History in Oslo, where archaeological ships were scanned with high accuracy and in a relatively short time. In addition, new methods for cultural heritage emerged. For a range of objects, UK universities

employed the multi-node texture mapping system (PTM), a novel method. PTM imaging was also employed by Oxford University on pottery, tablets, statues, and artifacts, with excellent analytical outcomes<sup>6</sup>. Since that period, and until the present time, the development of computers has continued at an accelerated pace. In 2014, a new generation of chips was manufactured containing twice the number of transistors compared to the previous generation<sup>7</sup>. 3D scanning operations in cultural heritage have developed rapidly, as will be explained later in the 3D section on scanning methods and techniques in digitizing cultural heritage.

### **3. 3D scanning: An effective tool for protecting and valuing cultural heritage.**

In the past two decades, 3D digitization of cultural heritage has become a common practice. The application of digitization technology in this field has significantly increased, driven by several key motives for digitizing cultural heritage:<sup>8</sup>

- Preserving the object's shape and texture in case of damage.
- Allowing the dissemination of 3D models publicly.

Developing highly accurate 3D representations of handicrafts, artifacts, and old documents is a challenging endeavor that calls for in-depth understanding of computer graphics and digitization methods. The entire process of digitizing cultural material can be altered by the latest developments in 3D scanning and photogrammetry.

By capturing an object's surface geometry and texture, 3D imaging creates both virtual and tangible 3D models that are

used to record cultural heritage. Digitization can go beyond only recording 2D items thanks to 3D imaging. It is frequently used to record historical artifacts for preservation by giving them a virtual structure, cutting down on processing, making access easier, and designing unique installations or restorations that eventually result in exact replicas of the original artifacts<sup>9</sup>. Virtual tourism, museums, educational materials, and the documentation of endangered heritage are just a few of the applications that use 3D models for identification, visualization, and animation<sup>10</sup>. One use for 3D imaging is conservation; for example, a lost object can be physically and digitally restored using white light scanning<sup>11</sup>. Laser scanning is used for the virtual reproduction of cultural artifacts, where laser scanning detects internal movement and combines laser-scanned data with multimodal or multispectral data to assess the conservation status of heritage paintings and papers.<sup>12</sup>

There are amazing Projects in 3D imaging. They focus on education and the preservation of culture from loss, such as the digital reconstruction of a war canoe found in the western Solomon Islands<sup>13</sup>. Often, 3D imaging can provide access to closed or restricted sites that are difficult to visit. 3D imaging can enable individuals to take a virtual journey through an era or archaeological area that is difficult to see. The use of 3D imaging and displays in a cave in Italy was a great case that made the cave appear to be from the Stone Age, including 3D data and writings on the cave walls that illustrate the most important characteristics of the Stone Age<sup>14</sup>. A wide range of professionals from different institutions to preserve cultural heritage 3D imaging. A study conducted by Hess (2015a; 2015b) demonstrated the use of 3D imaging to document cultural heritage objects. This technology is employed by various

professionals, including archaeologists, anthropologists, paleontologists, historians, computer scientists, surveyors, Egyptologists, museologists, biologists, engineers, and restoration specialists. They work in a variety of settings such as museums, universities, national organizations, charities, and media outlets. With reasons including digital documentation, developing digital substitutes to conserve cultural heritage, assessing artifact damage, tracking modifications to interactive exhibits, and educating and enhancing visitors' experiences at archaeological sites, more than half of the study participants actively used 3D imaging in their workplaces. The survey results used in this study indicated that participants used 3D imaging to photograph close-range objects.

This study accurately indicates the widespread use of 3D imaging for cultural heritage applications. The concerted efforts of several international organizations show that there is a greater interest in and continued support for the advancement and use of 3D imaging as a common and standardized technique for recording cultural resources. Initiatives that used 3D imaging, like the 2008-2012 European Project, have been carried out by groups like the International Society of Photogrammetry and Remote Sensing (ISPRS), the Scientific Committee of the International Council of Monuments and Sites (ICOMOS), and the International Committee for Documentation of Cultural Heritage (CIPA). The European Project developed tools for the formation of 3D collections to enhance technological advancements in the documentation of cultural heritage. From 2012 to 2015, this project focused on digitizing heritage, while

the Sketchfab initiative aimed to utilize 3D imaging for documenting cultural heritage by creating models and digitizing objects and sites. Additionally, the project highlighted the need for training workers through workshops on utilizing 3D imaging to preserve both tangible and intangible cultural heritage<sup>15</sup>.

Initiatives by the Europeana 3D Team and the Community Standards for 3D Data Preservation (CS3DP) project, which aim to inform, support, and encourage organizations that generate 3D data for cultural heritage preservation, are additional examples of the use of 3D imaging in cultural heritage preservation<sup>16</sup>. There are several 3D methods for recording cultural heritage objects, including passive image-based systems like photogrammetry and active-field-based methods like laser and white light scanning. There are two basic categories of modeling approaches for obtaining three-dimensional (3D) information about objects. While image-based approaches use passive sensors to capture two-dimensional (2D) images and use mathematical models to extract three-dimensional (3D) surface information, active sensor approaches use structured light or laser light to measure heritage artifacts directly. They use photogrammetry as well as other computer vision techniques that are more automated, such SFM. Computed tomography (CT), scanning, micro-CT scanning, and X-ray imaging are further 3D imaging methods that are used to document the dimensions and form of archaeological artifacts. Numerous research, like those by Wachowiak & Karas (2009) and Engel (2011), have employed these methods to conserve cultural heritage.

According to Remondino & Menna .the wide range of 3D technologies provides many options to choose from when planning to document an artifact or archaeological site. Each 3D

imaging method has a unique mix of benefits and drawbacks. These variables are influenced by the object's surface qualities, the degree of precision required for the documentation, the object's general attributes, location concerns, and the project budget. The choice of 3D technology can be influenced by a number of factors, including cost, usability, portability, operator experience, location issues, object attributes, and the overall documentation aim. Therefore, the availability of high-quality, high-resolution digital cameras and a range of inexpensive, open-source software systems has increased the frequency of cultural heritage preservation and reconstruction. This, in turn, has facilitated easier access to cultural heritag<sup>17</sup>. In addition, these technologies do not require an expert user, and the equipment used is flexible, easy to use and easy to obtain. Perhaps the most prominent advantages of using 3D imaging in documenting cultural heritage can be presented as follows: <sup>18</sup>

- The information needed for documentation and 3D modeling is contained in image data.
- It is possible to process old photos even if the object has been lost or altered.
- Compared to domain-based methods, obtaining images is quicker and simpler.
- 3D digital tools used in documenting cultural heritage are inexpensive, easy to carry from one place to another, easy to use, and provide the possibility of high accuracy.

Due to the numerous advantages of 3D imaging in preserving cultural heritage, image-based 3D reconstruction has become a popular method used in various publications and

articles. This technique has been applied in several studies, including the following:

- Rock Art, as examined by Plisson and Zotkina (2015)
- Ancient coins, studied by Hess and others (2018)
- Small artifacts, researched by Sapirstein (2018)
- Medium-sized sculptures, discussed by Menna and others (2016)
- Archaeological excavations, as described by Dellepiane and others (2013)

Additionally, 3D imaging has been utilized in the documentation of archaeological sites, such as in studies by Green and others (2014), Nocerino and others (2014), and Sapirstein (2016). A notable example includes the documentation of a 300-meter-long cave passage by Remondino and others (2016)<sup>19</sup>.

The technology has also been employed in the preservation of archaeological manuscripts, with significant contributions from Robson and others (2004), Remondino and others (2011a), Dellepiane and others (2013), and Abate and others (2014). Furthermore, underwater artifacts have been documented through studies by Guery and others (2017) and Menna and others (2018).

Additional applications of 3D imaging include the recording of Rock Art in studies by Lerma and Muir (2014), Noya and others (2015), Plisson and Zotkina (2015), and Jalandoni and others (2018). It has also been used in excavations, as evidenced by the work of Galeazzi (2016), DE Reu and others (2014), and Dellepiane and others (2013). In terms of architecture and temples, studies by Green and others (2014), Toschi and others (2014), and Remondino and others (2016) highlight its utility.

Finally, as Marziali and Dionisio (2017) show, 3D imagery has made it easier to create virtual museums. When taken as a whole, these research highlight how common 3D imaging is for recording cultural assets.

#### **4. 3D scanning and digitization of cultural heritage: The most important challenges.**

Despite the ease of applications used in 3D scanning, this does not mean that it can be used in all museums and archaeological sites. There can be a lot of variation in 3D data from museums and artifacts, including variations in color and geometric precision. It could seem like a decent visual representation, but in reality, the outcomes might not be traceable. Maintaining consistent 3D outputs may become more difficult due to the flexibility that facilitates image-based 3D reconstruction<sup>20</sup>. The wide variation in quality resulting from 3D imaging is a growing problem. Hess (2015b) surveyed the priorities for the quality of 3D imaging in cultural heritage documentation. Remondino, Nocerino, Toschi & Menna<sup>21</sup> noted that conference presentations often feature 3D image-based models; however, these conferences fail to address distortions and scaling issues. 3D imaging makes it possible for anybody to record cultural heritage, but it does not ensure precise or trustworthy reconstructions. Standards and criteria for assessing the process of using 3D images to document cultural resources are severely lacking.

According to Toschi, Nocerino, Hess, Menna, Sargeant MacDonald, Remondino, and Robson<sup>22</sup> the two main barriers to using 3D imaging to document cultural assets are a lack of

knowledge about the documentation process and the software used in it. They also suggested that people in charge of recording cultural heritage should focus on capturing surface features and precise surface geometry. This may be in line with the findings of the research conducted by Robinson et al. (2012)<sup>23</sup>. In its analysis of 3D imaging of museums, the study noted that there are 3D models inside museums that are not suitable for the artifact they are dealing with and that there are models that appear larger than the real artifact, which is a kind of contradiction.

### **5. 3D scanning methods and techniques for documenting cultural heritage:**

The term "Democratization" has emerged for 3D documentation of cultural heritage, which has made these techniques more flexible<sup>24</sup>. Images of objects or situations of various sizes and lighting conditions, both close and far away, can be taken with any digital camera, including portable ones. Additionally, there are mobile phone applications designed to create 3D models using the phone's built-in capabilities. Examples of these applications include "Qlone," "Trnio," and "Scann3D." These apps require minimal knowledge and can produce high-quality 3D models. They offer ready-made solutions that are easily accessible to non-expert users interested in heritage projects. These tools are ideal for 3D imaging of both tangible and intangible cultural heritage, providing a user-friendly option for 3D recording.

Photogrammetry commonly refers to the presentation and discussion of image-based 3D reconstructions used in documenting cultural heritage. Photogrammetry has a long history of paralleling photography<sup>25</sup>. There are a range of methods used in 3D photogrammetry, which are described using

other terms. The most commonly used methods for documenting cultural heritage include:

**- Photogrammetry:**

A branch of geomatics, sometimes known as surveying, photogrammetry is the scientific study of gathering, evaluating, and interpreting survey data pertaining to the Earth's surface. Making precise 3D measurements is the main goal of photogrammetry. Originally, it was employed for measuring architecture. The earliest examples of cultural heritage and preservation applications date back to 1858. Following the beginning of analytical photogrammetry in the 1950s, the transition to digital photogrammetry in the 1980s, and the notable development of photogrammetry technology in the 1990s due to the higher resolution of digital cameras, more details regarding the history and evolution of photogrammetry can be found in photogrammetry.<sup>26</sup>

The pinhole camera concept, in which every object point is equivalent to an image point, is used in photogrammetry. An image ray that travels past the camera's viewpoint center is defined by this connection. By recreating the ray beams that travel through this center, central projection photography can be used to ascertain the position and form of an object. A three-dimensional point in space can be defined by the intersection of two spatially distant rays. In this application, the internal direction refers to the visual geometry inside the camera, whereas the outer direction describes the spatial location and orientation of the camera. Different cameras may have different image geometries, even if photogrammetry is based on the

pinhole concept. This necessitates correction for any systematic deviations that each camera may have from the ideal pinhole model, as these discrepancies can lead to errors. The basic procedures of close-range photogrammetry include registration, preprocessing, orientation, measurement, and analysis.

Photogrammetry encompasses a variety of techniques that can be defined and classified in several ways. These classifications can be based on:<sup>27</sup>

1. Camera position and object distance include both aerial and close-range photogrammetry.
2. Number of Measurement Images: Stereo photography and single-image techniques fall under this category.
3. Recording Method: Photogrammetry can be classified into analogue, analytical, and digital methods.
4. Measurement Results: This distinction includes online and offline photogrammetry.

**6. Application or Specialized Field: An example here is architectural photogrammetry.**

**- Computer vision:**

The history of computer vision is more recent, having started with early studies into the visual perception component in the 1970s to provide robots intelligent behavior that mimics human intelligence. In contrast to photogrammetry's exact measuring objectives, computer vision uses mathematical algorithms to recreate three-dimensional shape and appearance<sup>28</sup>. Although they use distinct methods, photogrammetry and computer vision both begin with 2D photos and work their way up to 3D information. Whereas computer vision has concentrated on robotics and inspection, photogrammetry has concentrated on precision and dependability in mapping and monitoring. The SFM methodology, which uses image matching and bundle

modifications to simultaneously and automatically establish camera parameters and scene geometry, is one of the computer vision techniques that has been integrated. This approach relies on using multiple images to determine correspondences for image matching. This approach is the most widely used approach in image-based 3D reconstruction when dealing with cultural heritage<sup>29</sup>. The National Institute of Geographic and Forestry Information (IGN) developed the MICMAC technique, which serves as an example of this approach.<sup>30</sup>

This method has been extensively employed in the documentation of cultural heritage. In 2006 AD, a Russian business that specialized in computer vision technology released "Agisoft PhotoScan," which was used to document cultural heritage and create application tools for digital photogrammetry to protect cultural heritage (<sup>31</sup>). As a commercial program, it is continuously maintained and updated to integrate new processes and applications, it provides a comprehensive solution for documenting cultural heritage over other applications of the free "SFM" technology, which do not provide comprehensive solutions for documenting cultural heritage. Hence, the "Agisoft PhotoScan" program is a black box containing unknown information about the algorithms used in documenting cultural heritage<sup>32</sup>. PhotoScan has been the main program used in several cultural heritage studies, including those by Verhoeven (2011), Koutsoudis & Others (2013), 2014, De Reu & Others (2014), Clini & Others (2016), and Sapirstein (2016). The PhotoScan tool has been widely used; because of its affordability and power. The majority of consumers could not be aware of its advantages

and disadvantages, the tendency toward greater usability could result in a lack of understanding of the procedure and available tools as well as a rise in confidence in the 3D results.<sup>33</sup>

### **- CultLab3D application**

As one of the methods for digitizing 3D cultural heritage, some researchers at the Fraunhofer Institute for Computer Graphics Research in Germany have designed "CultLab3D", a mobile digitization laboratory, which digitizes artifacts in museums very quickly and at a low cost. It is able to capture the texture of artifacts, taking into account the properties of reflection and absorption so that realistic representations can be made even in poor lighting conditions.<sup>34</sup>

## **7. Conclusion:**

3D imaging is a powerful and innovative tool for preserving and restoring cultural heritage. By documenting landmarks and artifacts in minute detail, this type of imaging enhances the collective understanding of our history and culture, helping to transmit knowledge to future generations in an interactive way. It also contributes to creating an immersive experience that allows the public to explore heritage firsthand, enhancing personal connection to history. Furthermore, incorporating contemporary technologies into the arts and sciences raises public awareness of the value of heritage preservation and motivates society to take a more serious look at cultural challenges. As reliance on technology increases, we can expect 3D imaging to become an essential part of cultural identity preservation efforts, with the potential to create new methods of education and communication. Thus, 3D imaging remains a vital element in the efforts to preserve our cultural wealth, ensuring its sustainability for future generations.

## **8. Recommendations:**

The study arrived at the following suggestions:

1. Encouraging partnerships between cultural, academic, and technological institutions helps in the exchange of knowledge and expertise.
2. Putting clear standards for the quality and accuracy of 3D scanning data ensures consistency in documentation.
3. Providing specialized training programs for heritage workers to master the use of 3D scanning techniques.
4. Investing in modern technologies and developing tools used in scanning.
5. Organizing awareness campaigns raises awareness of the importance of digitization in preserving cultural heritage.
6. Supporting research and studies related to 3D scanning techniques and their impact on cultural heritage.
7. Developing government policies that support the use of digital technologies in preserving and documenting cultural heritage.

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