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FORMS OF PROTECTION AND PRESERVATION OF HISTORICAL CULTURAL HERITAGE (CASE STUDY)

A major problem associated with material cultural heritage is the ability to protect and preserve historic movable objects, such as sculptures, paintings, and various works of art. The traditional way has been to amass them in state or private collections, aiming to systematically record, catalog, describe, and photograph them. Due to various circumstances, including acts of theft and warfare, either paper inventories or the artworks themselves have often been lost. The lack of actual catalogs has made it impossible to reconstruct lists of museum objects, including those with significant historical and artistic value, making it difficult to search for and identify them in the future. With technological advances, a variety of media, including modern methods of digitization, have been used to enable universal access to cultural heritage. This article identifies stages in the evolution of the need for preserving and presenting cultural heritage, taking into account the advanced creation of three-dimensional reproduction.

Keywords: historic preservation, history, digitization, omnidirectional photography, museums.

1. INTRODUCTION

For technological reasons, the process of resource digitising was initiated by libraries. In the early 1990s, collections were processed on computers with electronic catalogues, inventories, and databases created primarily for library staff use. Scanning and sharing text was less complicated than digitising spatial objects (Piotrowicz, 2015). However, the digital revolution changed this situation. New tools and solutions allowed the digitisation process to encompass other museum collections. Digitisation and reconstruction techniques were also utilised in archaeology, architecture, and urban planning (Koryś, 2015). Digitisation meant managing, processing, searching, and delivering material

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electronically for museum entities, obtaining a digital version of an object, managing files, and sharing digital documentation (Kuśmirdowicz-Król, 2011).

An area currently requiring particular attention is three-dimensional digitisation. Digitisation of two-dimensional objects, such as paintings or photographs, is widely used in museums, unlike three-dimensional digitisation, which is not yet universally accepted as a standard in the field of museology. This is primarily because the issue itself can be approached in various ways. On the one hand, three-dimensional digitisation allows for representing objects as three-dimensional models, such as point clouds or composite structures. Alternatively, we can discuss the technique of omnidirectional photography, in which items are designated as photos overlaid on spheres to create the illusion of three-dimensionality. Both of these approaches have advantages and limitations, and the appropriate method should be based on the needs and goals of digitisation, taking into account aspects such as precision, efficiency, and fidelity to the original objects.

The article analyses the degree of digitisation of museum objects, taking into account EU directives and Polish programs related to digital culture, and indicates the potential and current technological possibilities in the field of spherical photography, setting directions for the development of digital technologies in this area, presenting the fundamental differences in various approaches to mapping.

2. THE DIGITISATION OF MUSEUM RESOURCES

The widespread digitisation of culture is an inevitable process, affecting not only the degree of its accessibility but also the protection of unique collections against destruction or loss. Modern technology allows for the creation of documentation related to the collections. It makes it possible to obtain and reproduce faithful copies of the item. It is crucial to convert an object into digital form to ensure its preservation in case of any damage or loss of the original. Additionally, digitisation allows for easy access to the entity from multiple locations simultaneously. Actions in this domain thus align with the fundamental tasks of museums, including collection, conservation, research, communication, education, and exhibition. The broader use of digital technologies results from the growing awareness of the role of museums as knowledge banks or data centres where you can find high-quality, authentic, professional information (Navarrete, 2021). It also reflects the increasing societal needs related to the widespread dissemination of culture. An example highlighting the significance of the digital cultural sector and the associated threats is UNESCO's Memory of the World program, initiated in 1992, which involves the creation of digital copies of world cultural monuments. The principles related to the protection and accessibility of collections are enshrined in the Republic of Poland Constitution, emphasising the transmission of heritage to future generations and ensuring equal access to culture (Konstytucja Rzeczypospolitej Polskiej…, 1997). However, the Act of November 21, 1996, on museums explicitly states that images of museum objects may be recorded and stored on digital data carriers (Ustawa z dnia 21 listopada 1996 r. o muzeach). Initially text-based in the DOS system, database systems were used at the National Museum in Warsaw and the National Museum in Poznań since 1989. Electronic systems were developed in over 80 museums from 1990 onwards, including the State Archaeological Museum in Warsaw. In 1992, the first electronic version of a database for cataloguing stolen and missing cultural property, listing losses from sacred objects, libraries, private collectors, and other institutions, was established (Barwik, Pasieczny,

2012). Poland's accession to the European Union brought new possibilities through, e. g., Regional Operational Programmes.

The traditional perception of museum collections has been complemented over time by the need for their digital dissemination. The European Commission's "i2010" initiative, introduced on June 1, 2005, focuses on digital libraries and obligates countries to support activities related to the digital sharing of libraries, archives, and museum resources (Zalecenie Komisji z dnia 24 sierpnia 2006 r. w sprawie digitalizacji…). In 2006, the EU Council published Conclusions on the Digitisation and Online Accessibility of Cultural Material, and Digital Preservation, designating digitisation and virtual accessibility of international cultural heritage as a strategic goal (Konkluzje Rady w sprawie digitalizacji…). The vision of a universal digital library was emphasised, encompassing various valuable elements of cultural heritage: texts, audiovisual materials, museum objects, archival records, and other resources of historical, artistic, or cultural value. The objectives for Member States for the coming years included the development and update of national plans and strategies for the digitisation of cultural heritage (2007), the establishment of a national system for long-term preservation and storage (2008), and the set of long-term quantitative and qualitative goals for storage, digitisation and virtual sharing cultural heritage (2008), and foster public-private cooperation in the field of digitisation (2007–2008) (Konkluzje Rady w sprawie digitalizacji…). A pioneering element was the recognition of the need for research on the socio-economic effects of long-term preservation of digital resources and on the socio-economic consequences for public goods (Konkluzje Rady w sprawie digitalizacji…, 2006). Several years later, the Commission Recommendations of October 27 2011, on the digitisation and online accessibility of cultural material and digital preservation were issued (Zalecenia Komisji z dnia 27 października 2011 r. w sprawie digitalizacji…). The act stressed the need to use modern information technologies to digitise and protect European cultural memory as a component of economic growth, job creation, and improved quality of life for Europeans.

During this time, Poland joined the Minerva+ program, and the Digitalization Team at the Ministry of Culture and National Heritage, established in 2006, formulated technical recommendations for digitising collections. In 2007, the "Cultural Heritage" digitisation program was launched, followed by the "Creation of digital resources of cultural heritage" in 2007–2009. At that time, 12 state archives had the infrastructure for digitising and storing digital data, and 119 museums began computerisation in the form of electronic inventories (Digitalizacja dóbr kultury w Polsce…, 2015).

In 2009, the digital resources of state archives were estimated at approx. Three million scans, and in libraries – at approx. three hundred thousand library units (approx. 15-17 million scans), museum objects at approx. three hundred thousand reproductions (Raport o digitalizacji, 2009). Meanwhile, cultural institutions housed immovable monuments listed in the register of monuments (63,368 objects), archival units of archival materials in state archives (260 km of current archival materials, equivalent to over 35 million archival units, ranging from 1 to over 1000 pages), museum collections (12 million), and library materials (6,227,756 units) (Digitalizacja dóbr kultury w Polsce…, 2015). Despite the issuance of further recommendations and EU directives, these were the last comprehensive data in this area. Implementing the Multiannual Government Program "Culture+" from 2011 to 2015 aimed to increase the acquisition of digital records.

In the "Social Capital Development Strategy 2020" from 2013, it was explicitly emphasised that "Digitization is currently a key process contributing to the country's development, as it offers a chance for the preservation of heritage resources, enhances the

efficiency of access to these resources, thereby fostering contemporary cultural creativity and the development of creative potential" (Uchwała nr 61 Rady Ministrów z dnia 26 marca 2013 w sprawie przyjęcia „Strategii Rozwoju Kapitału Społecznego 2020"). The strategy also noted that "Given the contemporary ways of participating in culture dominated by new technologies, a significant task of public policy is to support the process of digitising cultural heritage" (Uchwała nr 61 Rady Ministrów z dnia 26 marca 2013 w sprawie przyjęcia „Strategii Rozwoju Kapitału Społecznego 2020"). The wide availability of the collections was intended to eliminate barriers to access to cultural heritage, especially among people at risk of social exclusion (Kowalik, Komusińska, Strycharz, Maźnica, 2016).

As revealed by analyses conducted in 2015 among 32 museums under the auspices and co-supervision of the Ministry of Culture and National Heritage, only nine museums provided online catalogues. These museums collectively published 137,880 objects, of which 84,830 were digital reproductions (Ciemniewska, Pliszka, 2016). At that time, the most extensive collection belonged to the National Museum in Krakow, with 103,000 records. Of the remaining 533 museums, only 19 provided collection catalogues, presenting 101,884 objects, including 83,148 digital reproductions (Ciemniewska, Pliszka, 2016). Three goals for digitising cultural goods in Poland in 2009-2020 were identified: expanding Polish digital resources, protecting digital resources, and ensuring access to digital resources (Program digitalizacji dóbr kultury…, 2009). Priority in digitisation work was to be given to materials based on their usefulness (frequent use of the object), poor preservation status (as protection against its loss), value and uniqueness of the entity, the necessity of complementing the digital collection, limited accessibility of the object, particular significance of the resources for national or regional culture (Program digitalizacji dóbr kultury…, 2009). A crucial aspect of activities related to digitising museum collections was the publication of the National Institute for Museology and Monument Protection's Catalog of Best Practices (Katalog dobrych praktyk, 2021). This document contained detailed instructions regarding the reproduction of museum artefacts and their dissemination, providing valuable guidance for digitalisation.

Currently, the achievements in this area are highly insufficient on institutional, research, and social dimensions. Virtual sharing of collections played a crucial role during the COVID-19 pandemic. In 2020, 50.9% of museums in Poland limited their operations (Kultura w 2020 r., 2021), partially shifting their activities to the virtual realm. Through online channels and social media, 1367 virtual exhibitions were made available (Kultura w 2020 r., 2021). In 2021, 502 virtual exhibits were viewed by 1.2 million people, along with 7,200 outreach events that engaged 3.9 million participants (Kultura i dziedzictwo narodowe w 2021 r., 2022). Museums with tools and programs for managing digital objects use them in conservation and research work and in identifying artefacts or reconstructing, modelling, and restoring monuments (Program digitalizacji dóbr kultury…, 2009). Technological progress, particularly in precise representations of spatial objects through spherical photography, is a crucial element in this context.

3. INTRODUCTION TO SPATIAL PHOTOGRAPHY

In the case of spherical photography, we represent three-dimensional objects using photographs placed on a sphere in such a way as to create the illusion of three-dimensionality. This allows users to interact with the image in a full 360-degree horizontal

and 180-degree vertical range. This type of photography is also known as panoramic or spherical photography.

Creating spherical photography involves capturing diverse photographs from miscellaneous perspectives to represent the object from every side. Subsequently, these photos are stitched together into a panoramic image, or visualisation methods based on dynamically generated pictures are employed, depending on the camera's settings. Figure 1 illustrates the composition of 6 photos (Z1-Z6) in such a way as to enable the visualisation of object A. In this case, the photos were taken from the outside of the object. For object B, where the goal is to capture the representation of the object from its interior, which may be helpful, e.g., in the case of rooms or the interiors of storage objects such as crates, photos are taken from the object's geometric center whenever possible. These photos are then merged. There are several techniques for obtaining a spherical effect, with differences primarily arising from the type of lens used to take the photo. Wide-angle or standard lenses can be used, and these choices will affect distortions in the representation and the speed of image capture. Some distortions may be removed using appropriate software, but this typically comes at the expense of image quality.

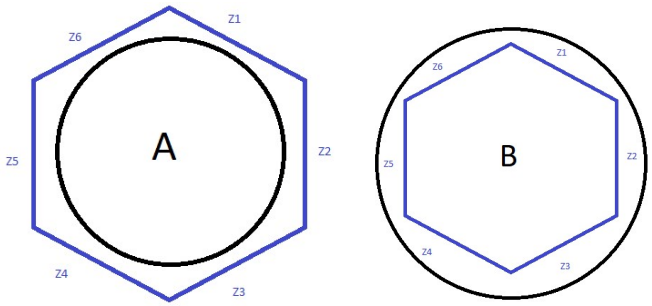

Figure 1. A schematic presentation of spherical photography as a composition of partial photographs

Source: own work.

In the case of representing a three-dimensional object, an additional dimension must be introduced, where the photos are taken at an angle “a” relative to the horizontal plane, as illustrated in Figure 2.

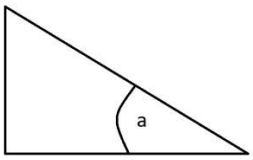

Figure 2. Visualization of the photo angle changes to the base plane

Source: own work.

Spherical photos placed on a spherical surface allow for complete immersion and interaction with the image. Users can explore the picture, rotate around horizontal and vertical axes, zoom in or out, and discover details from various perspectives. Spherical

photography is highly promising in museum collection digitisation, as it enables users to explore and view objects with varying levels of precision from any location and at any time. Furthermore, spherical photography can be utilised in scientific research, historical reconstructions, or the creation of virtual exhibitions.

However, it is crucial to distinguish between representation aiming to provide an opportunity to acquaint oneself with a specific exhibit and the availability of high-resolution photos enabling the examination of objects' morphological features.

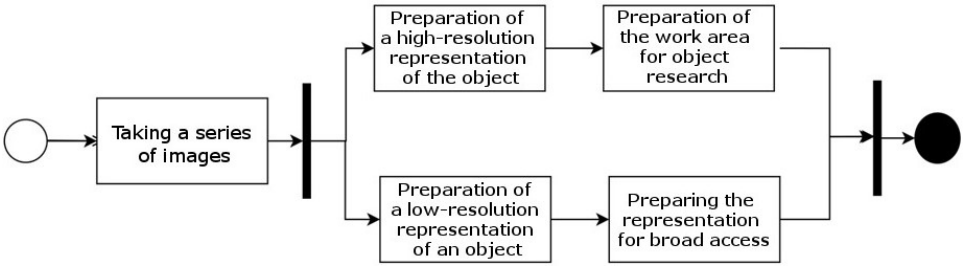

Figure 3. Preparation of different access to photographic representations of the object

Source: own work.

To determine the current technological capabilities in spherical photography, a study was conducted involving reproducing an object – a cup with a saucer – from a Silesian porcelain factory in Parowa (German: Tiefenfurt, Bolesławiec county). The thing bears the signature used between 1885 and 1896 (Schlesische Porzellanfabrik from the Lövinsohn and Donath period).

The equipment used comprised a set consisting of a table for three-dimensional photography (TopShow3D® MINITABLE TSM) and a full-frame camera (CANON) with a 26 Mpx sensor (6240 x 4160 px) and an adjustable focal length lens ranging from 24–105 mm. The table consists of a glass plate that can rotate in the horizontal plane and a trolley with a tripod that can move along a semicircular rail placed in the vertical plane.

Figure 4. TopShow3D® MINITABLE TSM

Source: TopShow3d, https://topshow3d.net/en/minitable.

The table allows photographing the object rotated at any angle in the horizontal plane (with an accuracy of up to 1 degree), creating a 360-degree panoramic photo composed of a maximum of 360 pictures taken at different angles. Additionally, the camera's tilt angle adjustment is possible from 0 to 90 degrees with an accuracy of 1 degree, enabling the capture of a 3D photo of the object from the top and, by manually flipping the object upside down, a 3D photo of the entire thing. Considering the inversion of the object, 181 angles of the camera relative to the object (in the vertical plane) are available.

Combining rotations in different planes makes it possible to capture 65,160 distinct photos of the same object, which (at an average photo size of 1 MB) would take up approximately 64 GB of disk space.

The object's height or diameter for the used table cannot exceed 40 cm. The limitations mentioned above and photo margins (2.5 cm on each side) are considered in the table below, which presents the maximum object dimensions (for a single photo), the camera's field of view, practical resolution, and unit resolution for the horizontal plane depending on the lens focal length.

Table 1. Technical specifications of the lens used depending on the focal length

lens focal length	**24**	**35**	**50**	**70**	**85**	**105**
maximum width [cm]	40	40	40	30	25	20
visibility angle [°]	71,9	60,8	36,8	27,2	22,8	17,9
practical resolution [px]	2480	3510	5050	5320	5130	4900
unit resolution [px/cm]	62,0	87,8	126,3	177,3	205,2	245,0
unit resolution [px/°]	86,8	102,6	169,6	229,4	273,7	348,6

Source: own work.

The following formula expresses the horizontal total resolution of a 360-degree (panoramic) image as a function of a single rotation angle (***α***), that is, the number of component images and the diameter of the object in pixels (***d***).

$$resolution = \frac{360°}{\mathrm{a}} * d * sin\frac{\mathrm{a}}{2}$$

The table shows the values for an object with a diameter of 4000px and several selected angles, along with the ratio to the reference value (for an infinitely small rotation angle).

Table 2. 360-degree photo resolution depending on the angle of one rotation

rotation angle [°]	*resolution [px]*	*ratio to reference value [%]*
1	12566,21	99,999
2	12565,73	99,995
5	12562,38	99,968
10	12550,43	99,873
30	12423,31	98,862
45	12245,87	97,450
60	12000,00	95,493

Source: own work.

It should be noted that the resolution indicated in Table 2 applies only to the mapping used in the context of visualisation. For scientific research purposes, primary images will be used, which, in the case of rotation by 1 degree, will generate a mapping of the object's surface, which will be measured in gigapixels. Such a high resolution will not be needed for most applications, nor will it be useful.

A separate issue closely related to digitisation, whether two or three-dimensional, which should be addressed, is identifying the photo's object and removing unnecessary elements, such as the background. For two-dimensional mappings, this task can be done manually. However, manual background removal would be computationally demanding and time-consuming for spherical photos. Considering the number of photographs required to create a high-quality spherical representation, with 36 pictures per rotation and ten plane angle settings, one would face removing the background in 360 images. Hence, there is a need to automate this process, and image segmentation must be done very accurately to ensure the entire object is present in the scene after the procedure's completion. The general approach to this problem is illustrated in Figure 5.

Figure 5. The original photo of the object (on the left) and after segmentation (on the right)

Source: own work.

4. CONCLUSIONS

The digitisation of collections is a response to many contemporary challenges related to the destruction or loss of national heritage assets and the growing societal need for broad access to culture. Although attempts at universal digitisation began in Poland over two decades ago, the quantity of virtually accessible collections is still insufficient. Current issues include but are not limited to the lack of digital inventories, detailed data on progress in digitisation within museum objects, standardisation of digitisation, and a shared platform for virtual versions. Another essential problem is the lack of a uniform approach to storing and exchanging information about museum collections, which would enable flexible changes in the data structure in line with changing needs. Traditional databases and commonly used 2D scanning are currently insufficient and too inflexible for the diverse collections gathered in museums.

The development of digital technologies, particularly advancements in computer graphics and photogrammetry, has significantly influenced the approach to digitising museum collections. Three-dimensional imaging, a relatively new solution in digitisation, allows faithful representation of spatial objects. To further advance the digitisation of

museum collections, it is necessary to develop standards and guidelines that define best practices and general principles for three-dimensional digitisation. Additionally, it is essential to continue research into developing digital technologies, such as modern 3D scanning methods, visualisation and interaction techniques, and ways to present and make digitised museum collections attractive and accessible to a broad audience. Conclusions drawn from conducted research and the development of new technologies in digitising museum collections can significantly impact preserving, studying, and making cultural heritage accessible. However, to achieve the full potential of digitisation, ongoing research is necessary, along with improving inter-institutional collaboration to develop innovative solutions in museum information management and the application of digital technologies. A new challenge in creating and sharing museum collections is defining an ontology describing the museum collections domain or adapting more general solutions, such as the Semantic Knowledge Base. Using ontologies can enable a more comprehensive and flexible representation of data, contributing to better managing museum resources and facilitating information exchange between different institutions.

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