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VIRTUAL MUSEUMS AS A NEW CULTURAL SPACE

Abstract. The purpose of this article *is to provide a comprehensive analysis of virtual museums as a new cultural space, to determine their place within the contemporary system of preserving, representing, and interpreting cultural heritage, and to examine the impact of digital technologies on the transformation of museum communication, cultural memory, and interaction between museums and their audiences.* ***The methodological framework*** *is based on an interdisciplinary approach that integrates methods from museum studies, cultural anthropology, digital humanities, and heritage studies, combined with the principles of systemic, historical-comparative, structural-functional, and cultural-anthropological analysis. The application of this comprehensive methodology makes it possible to trace the evolution of virtual museums from electronic catalogues to interactive digital platforms that facilitate new forms of creating, interpreting, and disseminating cultural knowledge. The study demonstrates that the digitalization of the museum sector has fundamentally*

transformed the traditional functions of museums, shifting them from institutions primarily concerned with the physical preservation of artefacts to open digital cultural spaces where heritage preservation, scholarly communication, education, virtual representation, and cultural interaction converge. Particular attention is devoted to the application of three-dimensional modelling, virtual and augmented reality, artificial intelligence, digital reconstruction, and online platforms as key drivers of expanding public access to museum collections and fostering new models of cultural participation. ***The scientific novelty*** *of the study lies in its comprehensive conceptualization of the virtual museum as an autonomous socio-cultural phenomenon that functions not merely as a digital extension of the traditional museum but as a new type of cultural space that transforms the mechanisms of cultural heritage representation, the construction of collective memory, and the interaction between cultural institutions and society. It is concluded that virtual museums have become one of the leading directions in the development of contemporary museum policy, contributing to the democratization of access to cultural heritage, the expansion of international cultural communication, the preservation of digital cultural resources, and the emergence of new models of public participation in the preservation, interpretation, and promotion of cultural heritage.*

Key words: *virtual museum, museum digitalization, cultural heritage, digital humanities, cultural anthropology, museum communication.*

ВІРТУАЛЬНІ МУЗЕЇ ЯК НОВИЙ КУЛЬТУРНИЙ ПРОСТІР

Анотація. Метою статті *є комплексний аналіз феномену віртуальних музеїв як нового культурного простору, визначення їхнього місця у сучасній системі збереження, репрезентації та інтерпретації культурної спадщини, а також дослідження впливу цифрових технологій на трансформацію музейної комунікації, культурної пам'яті та взаємодії між музеями й аудиторією.* ***Методологічну основу дослідження*** *становлять міждисциплінарний підхід, що поєднує методи музеєзнавства, культурної антропології, цифрової гуманітаристики та heritage studies, а також принципи системного, історико-порівняльного, структурно-функціонального й культурно-антропологічного аналізу. Використання комплексної методології дало змогу простежити еволюцію віртуальних музеїв від електронних каталогів до інтерактивних цифрових платформ, що забезпечують нові форми створення, інтерпретації та поширення культурного знання. Установлено, що цифровізація музейної сфери суттєво змінює традиційні функції музею, перетворюючи його з інституції фізичного зберігання артефактів на відкритий цифровий культурний простір, у якому поєднуються збереження спадщини, наукова комунікація, освіта, віртуальна репрезентація та культурна взаємодія. Особливу увагу приділено використанню технологій тривимірного моделювання, віртуальної та доповненої реальності, штучного інтелекту, цифрової реконструкції та онлайн-платформ як чинників розширення доступу до музейних колекцій і формування нових моделей культурної участі.* ***Наукова новизна*** *дослідження полягає у комплексному осмисленні віртуального музею як самостійного соціокультурного феномену, що функціонує не лише як цифрове доповнення традиційного музею, а й як новий тип культурного простору, який трансформує механізми репрезентації культурної спадщини, формування колективної пам'яті та взаємодії між культурними інституціями й суспільством. Зроблено* ***висновок,*** *що віртуальні музеї стають одним із провідних напрямів розвитку сучасної музейної політики, сприяючи демократизації доступу до культурної спадщини, розширенню міжнародної культурної комунікації, збереженню цифрових культурних ресурсів та формуванню нових моделей участі громадськості у процесах збереження, інтерпретації й популяризації культурної спадщини.*

Ключові слова: *віртуальний музей, цифровізація музеїв, культурна спадщина, цифрова гуманітаристика, культурна антропологія, музейна комунікація.*

Problem Statement. The digital transformation of contemporary society has fundamentally reshaped the ways in which cultural heritage is created, preserved, represented, and consumed. Whereas, until the late twentieth century, the museum was primarily understood as a physical institution rooted in a specific location, material collections, and conventional modes of visitor engagement, the rapid advancement of digital technologies in the twenty-first century has prompted

a profound reconceptualization of the very nature of museum space. The widespread adoption of high-speed Internet, three-dimensional (3D) modelling, virtual and augmented reality (VR/AR), photogrammetry, artificial intelligence (AI), and cloud-based technologies has created the conditions for the emergence of a new type of cultural institution – the virtual museum.

This transformation has become particularly significant in recent years. The COVID-19 pandemic demonstrated the critical importance of digital communication channels between museums and society, transforming online engagement from a supplementary tool into one of the core dimensions of museum practice. At the same time, Russia's military aggression against Ukraine has confronted the museum sector with unprecedented challenges related to the preservation of cultural heritage under conditions of physical destruction, occupation, and the unlawful removal of cultural property. Under these circumstances, the digital documentation of heritage assets, the development of virtual exhibitions, and the creation of digital archives have acquired not only cultural but also legal, memorial, and security significance.

The contemporary virtual museum can no longer be understood merely as an electronic catalogue of museum collections or a digital replica of a traditional exhibition. Rather, it is increasingly evolving into an autonomous cultural environment that integrates the functions of heritage preservation, scholarly research, public dissemination, education, social communication, and interactive audience engagement. Simultaneously, the digitalization of the museum sector has generated a range of complex theoretical and practical challenges concerning the authenticity of digital representations, digital inequality, the long-term preservation of digital resources, intellectual property rights, the ethical implications of artificial intelligence, and the relationship between physical and virtual museum experiences.

Despite the substantial growth of scholarship on digital cultural heritage, existing studies have predominantly focused either on specific technological solutions or on individual museum projects. Considerably less attention has been devoted to the development of an integrated conceptual framework that examines the virtual museum as a new mode of cultural space, combining institutional, technological, sociocultural, and memorial functions. Such an approach is particularly relevant in the Ukrainian context, where the digital transformation of the museum sector is unfolding simultaneously with the urgent need to document war crimes, safeguard cultural heritage, and develop new practices of cultural memory in the context of ongoing armed conflict.

Aim of the Study. The aim of this article is to provide a comprehensive analysis of the phenomenon of virtual museums as a new form of cultural space, to determine their role within the contemporary system of preserving, representing, and interpreting cultural heritage, and to examine the impact of digital technologies on the transformation of museum communication, cultural memory, and interactions between museums and their audiences.

Literature Review. The digital transformation of museums and the emergence of virtual museums as a new cultural space have become one of the most dynamic areas of contemporary museum studies, digital humanities, and heritage studies. The theoretical foundations for the functioning of museums in the digital era are reflected in the revised museum definition adopted by ICOM, which emphasizes accessibility, inclusivity, community participation, and the use of advanced technologies in the preservation and dissemination of cultural heritage [1]. Comprehensive analyses of the development of virtual museums, digital exhibitions, extended reality (XR), three-dimensional (3D) modelling, and interactive platforms have been presented in the works of H. Cui and J. Wu [2], Z. Song and L. Evans [3], D. Aiello *et al.* [4], F. Tian *et al.* [11], O. Yezhova *et al.* [12], and H. Wang *et al.* [21]. These studies demonstrate that contemporary digital technologies are reshaping not only the methods of presenting museum collections but also the very model of interaction between museums and their audiences, fostering new forms of cultural communication, participation, and public engagement.

A substantial body of recent scholarship has focused on the digital transformation of museums in the aftermath of the COVID-19 pandemic, which acted as a catalyst for the rapid adoption of online exhibitions, digital services, and remote visitor engagement [5–9]. Another important line of research addresses the digital preservation of cultural heritage during armed conflict. Particular attention has been devoted to the Ukrainian experience of employing 3D scanning, virtual museums, and digital heritage repositories for documenting, preserving, and promoting cultural heritage under conditions of Russia's military aggression [13–20]. Nevertheless, an analysis of the current historiography indicates that, despite the growing number of publications, most studies remain focused on specific technological dimensions of museum digitalization. Comparatively little attention has been paid to a holistic conceptualization of the virtual museum as an autonomous sociocultural phenomenon and a new form of cultural space that transforms the mechanisms of cultural heritage representation, the construction of collective memory, and the relationships between museums, society, and digital communities. It is these issues that constitute the central focus of the present study.

Main Findings. The classical understanding of the museum has long been grounded in its institutional status as a permanent, non-profit organization responsible for acquiring, preserving, researching, interpreting, and publicly presenting cultural heritage. This perspective is reflected in the revised definition adopted by the International Council of Museums (ICOM) in 2022, according to which a museum is a public-serving institution that «acquires, conserves, researches, communicates and exhibits tangible and intangible heritage» [1]. However, the ongoing digital transformation of the cultural sector has substantially expanded the traditional boundaries of museum practice. Increasingly, the museum functions not only as a physically localized institution but also as a multidimensional communicative environment in which the creation, preservation, interpretation, and dissemination of cultural heritage are progressively embedded within digital ecosystems. Consequently, digitalization has transformed not merely the technological modes of presenting museum collections but also the very concept of museum communication, audience engagement, and the production of cultural meaning.

One of the most significant manifestations of this institutional transformation has been the emergence of the virtual museum. Its development has been driven by the interaction of several interrelated processes. First, rapid advances in digital technologies for the representation of cultural heritage – including three-dimensional (3D) scanning, photogrammetry, virtual reality (VR), augmented reality (AR), and artificial intelligence (AI) – have dramatically expanded the possibilities for documenting and interpreting museum collections. Second, broader sociocultural changes associated with the democratization of access to cultural resources, the expansion of digital culture, and the transformation of museum–audience relationships have redefined expectations regarding public participation and accessibility. Third, the global crises of the past decade – including the COVID-19 pandemic, armed conflicts, and natural disasters – have underscored the necessity of digital documentation and the long-term preservation of cultural heritage. Under these circumstances, the virtual museum is increasingly understood not merely as a supplementary digital extension of the traditional museum but as an autonomous cultural space that performs functions of preservation, communication, education, memorialization, and international cultural exchange.

The concept of the *virtual museum* emerged in the late twentieth century in parallel with the rapid development of information and communication technologies and the gradual digitization of cultural heritage. During its initial stage (the 1990s to the early 2000s), the term primarily referred to electronic catalogues of museum collections or institutional websites that provided remote access to object descriptions and digital images. At that time, digital technologies performed predominantly supportive functions by enhancing public access to museum collections without fundamentally transforming the traditional model of museum communication. It was during this period that the

first international standards for digital documentation and computer-based visualization of cultural heritage were established, emphasizing, among their core principles, the provision of open access to cultural resources [2].

The subsequent evolution of the virtual museum was driven not only by technological innovation but also by a profound reconceptualization of museum practice itself. Throughout the 2010s, digital technologies ceased to be regarded merely as auxiliary tools for presenting collections and became increasingly integrated into every dimension of museum activity, including collection management, scholarly research, interpretation, exhibition design, and audience engagement. Advances in high-performance computer graphics, three-dimensional (3D) modelling, photogrammetry, virtual reality (VR), and augmented reality (AR) substantially expanded the possibilities for representing cultural heritage in digital form, transforming the virtual museum from an informational repository into an interactive environment for cultural communication. This transition reflects a broader paradigm shift in museum studies, whereby digital technologies are no longer perceived simply as instruments for reproducing physical collections but as integral components of new modes of heritage production, interpretation, and public participation. Consequently, the virtual museum has evolved into a dynamic platform that enables immersive experiences, collaborative knowledge creation, and transnational access to cultural heritage, fundamentally redefining the relationship between museums, their collections, and diverse global audiences.

In contemporary museum studies, the virtual museum is increasingly conceptualized as an autonomous digital cultural space rather than merely a digital replica of a traditional museum exhibition. Accordingly, the nature of interaction between visitors and museum objects has undergone a fundamental transformation: passive engagement with digitized materials has been replaced by interactive experiences that enable exploration, navigation, personalization, and collaborative engagement with digital collections.

According to the degree of digital integration, contemporary scholarship generally distinguishes several principal forms of virtual museum environments: online digital collections, virtual tours based on panoramic imaging or 360-degree video, three-dimensional (3D) reconstructions of individual artefacts and museum spaces, fully immersive virtual reality (VR) environments, and augmented reality (AR) systems that integrate digital content into physical museum settings [3]. Rather than constituting mutually exclusive models, these formats increasingly coexist within integrated digital museum ecosystems, where different technologies complement one another to enhance accessibility, interpretation, and visitor engagement.

Despite the widespread adoption of digital museum practices, there is still no universally accepted definition of the concept of the *virtual museum*. Existing definitions reflect diverse scholarly perspectives, including technological, informational, communicative, cultural, and museological approaches. These differences primarily arise from divergent understandings of the principal function of the virtual museum – whether it is viewed as a platform for the digital presentation of collections, an interactive environment for user engagement, or a new space for cultural production and knowledge creation.

One of the most frequently cited definitions is that proposed by D. Aiello and colleagues, who define the virtual museum as a digital institution that enables interactive exploration of cultural objects irrespective of the user's physical location [4]. Within this framework, the defining characteristics of the virtual museum are interactivity, remote accessibility, and the possibility of non-linear engagement with museum content, thereby extending the museum experience beyond the spatial and temporal constraints of the physical institution.

A similar perspective is reflected in the position of the International Council of Museums (ICOM), which emphasizes that digital technologies substantially extend the temporal and spatial

boundaries of museum practice by providing access to collections regardless of visitors' geographical location while creating new opportunities for public communication through digital platforms and social media [5]. From this perspective, the virtual museum should be understood not simply as a technological solution but as a new institutional model that fundamentally reshapes the operation of museums in the digital age.

Within the framework of this study, the virtual museum is defined as a digital cultural space that provides access to both tangible and intangible cultural heritage through contemporary information and communication technologies, creates an interactive environment for engagement between users and cultural objects, and performs the core museum functions of preservation, interpretation, communication, and public dissemination independently of the physical boundaries of conventional museum institutions. This conceptualization makes it possible to analyse the virtual museum not as a technological extension of the traditional museum but as an autonomous form of cultural representation emerging within the broader context of the digital transformation of contemporary society.

Although the digitalization of the museum sector began long before the COVID-19 pandemic, the global health crisis marked a decisive turning point by transforming digital innovation from a gradual process into an institutional necessity. The closure of museums across most countries placed their core public functions – including access to cultural heritage, educational activities, and cultural communication – under unprecedented pressure. Under these circumstances, digital environments ceased to serve merely as complementary tools and instead became the primary channel through which museums interacted with society.

According to the International Council of Museums (ICOM), approximately 95% of museums worldwide were temporarily closed to physical visitors during the pandemic, while the overwhelming majority significantly expanded their digital presence. More than half of museums substantially increased their activity on social media, broadened their range of online exhibitions, educational programmes, and interactive digital services [6]. Consequently, the pandemic dramatically accelerated the digital modernization of the museum sector, compressing into a short period a process that might otherwise have unfolded over many years.

The quantitative outcomes of this digital adaptation further illustrate the scale of this transformation. For example, the virtual exhibition *The New PK – Fighting the New Coronavirus*, launched in China, attracted more than five million visitors during its first month online [7]. Likewise, an international survey conducted by ICOM-AVICOM and ICOM-MPR involving 173 museums from 51 countries documented a rapid expansion of digital content and the emergence of new forms of museum communication, including podcasts, live-streamed events, multimedia lectures, digital educational platforms, and virtual guided tours [8]. These findings demonstrate that the pandemic not only accelerated the technological modernization of museums but also fundamentally transformed the relationship between cultural institutions and their audiences, establishing digital engagement as an essential component of contemporary museum practice.

The most significant consequence of the COVID-19 pandemic has been the fundamental redefinition of the role of digital space within museum practice. Prior to 2020, digital resources were generally regarded as supplementary components of conventional exhibition activities. In the post-pandemic period, however, they have increasingly come to be recognized as a fully integrated dimension of museum operations, embedded within collection management, research, exhibition development, educational programming, and communication with audiences.

Contemporary scholarship increasingly emphasizes that digitalization is no longer a temporary response to exceptional circumstances but has evolved into a long-term strategic direction for museum development. The automation of routine tasks, the application of artificial intelligence (AI) to collection cataloguing, digital analysis, and the personalization of museum content enable

museum professionals to devote greater attention to activities requiring creative interpretation, critical thinking, public engagement, and the construction of cultural narratives [6]. In this respect, digital technologies do not replace the traditional functions of museums; rather, they fundamentally transform the nature of museum professionals' work by shifting the emphasis from administrative routines toward interpretation, mediation, and knowledge production.

The pandemic has also profoundly reshaped patterns of museum audience behaviour. These changes have been particularly evident among members of Generation Z, for whom digital environments constitute the primary context for accessing information and experiencing culture. A growing body of empirical research demonstrates that COVID-19 not only accelerated the digital transformation of cultural institutions but also altered patterns of cultural consumption by generating sustained demand for interactive, personalized, and multimedia forms of engagement with cultural heritage [9]. As a result, a strong digital presence has ceased to represent a competitive advantage and has instead become an essential prerequisite for the effective functioning of museums within the contemporary cultural landscape.

Consequently, the COVID-19 pandemic should be interpreted not merely as a temporary episode in the history of museum digitalization but as a critical turning point in institutional transformation. It marked the emergence of a new operational model in which physical and digital dimensions of museum communication are integrated into a unified and complementary framework for preserving, interpreting, and disseminating cultural heritage.

Virtual Reality (VR) and Augmented Reality (AR) technologies have become central components of the digital infrastructure of the contemporary virtual museum. Their application has long moved beyond the experimental stage and now represents one of the principal directions in the digital representation of cultural heritage. Unlike conventional digital collections, VR and AR technologies provide not only enhanced visualization of museum objects but also immersive and interactive environments in which users become active participants in the process of knowledge creation rather than passive recipients of information.

Recent meta-analyses indicate that the application of VR and AR technologies positively influences visitor engagement, depth of understanding of cultural content, emotional immersion, perceptions of authenticity, and educational effectiveness [10]. At the same time, it has become increasingly evident that the success of digital museum environments depends less on technological sophistication than on the quality of their museological design. In other words, the educational and cultural value of immersive technologies is determined not by the technologies themselves but by the interpretative frameworks within which they are embedded.

A particularly illustrative example is provided by the study of Lee and Ch'ng (2022), who proposed a hybrid VR/AR environment designed to facilitate collaborative engagement with digital cultural heritage objects. Their model enables users operating within different digital environments to examine museum artefacts collectively and to construct shared interpretations through interactive participation. The authors convincingly demonstrate that cognitive engagement is determined primarily by the design of interaction scenarios – specifically, users' ability to manipulate digital objects, navigate virtual environments collaboratively, and participate in the collective interpretation of cultural heritage – rather than by the mere implementation of VR or AR technologies [10]. This finding highlights an important principle of contemporary museum digitalization: immersive technologies create the potential for new forms of museum experience, but the quality and significance of that experience ultimately depend on the conceptual design of museum communication and the interpretative strategies through which digital heritage is presented to diverse audiences.

The technological foundation of the contemporary digital museum is formed by three-dimensional (3D) heritage documentation techniques, particularly laser scanning, photogrammetry,

and digital modelling. These technologies enable the creation of highly accurate digital representations of museum objects, architectural monuments, and historic environments that can be employed for scholarly research, conservation and restoration, virtual exhibition, and the long-term digital preservation of cultural heritage [3].

Unlike conventional photographic documentation, three-dimensional modelling captures not only the external appearance of an object but also its spatial geometry, surface texture, chromatic properties, and structural characteristics. Consequently, a digital model is no longer merely an illustration of a museum artefact; it becomes an independent scholarly resource capable of supporting further research, digital reconstruction, conservation planning, and diverse forms of virtual representation. In this sense, 3D documentation contributes to a fundamental shift from the static recording of cultural objects toward the creation of dynamic digital heritage assets with enduring scientific and educational value.

Three-dimensional documentation technologies have acquired particular importance in contexts where cultural heritage has been damaged, destroyed, or rendered inaccessible. Under such circumstances, digital models perform not only informational functions but also memorial, documentary, and evidential roles. A study devoted to the digital reconstruction of Bronze Age artefacts from the Sanxingdui archaeological complex in China demonstrated that the integration of high-precision 3D scanning with multimodal visualization technologies creates an entirely new framework for interacting with museum objects, combining spatial, visual, simulated tactile, and auditory dimensions of heritage experience [11]. Accordingly, three-dimensional documentation should be regarded not merely as a preservation technology but also as a powerful instrument for developing new models of cultural communication and public engagement.

The next stage in the evolution of digital museums is characterized by the integration of artificial intelligence (AI), which is progressively transforming the organization of museum content and the nature of visitor interaction. Whereas the first generations of digital museums generally provided identical informational content to all users, contemporary machine learning algorithms enable the development of personalized museum experiences tailored to individual interests, levels of prior knowledge, linguistic preferences, and behavioural patterns.

Recent studies demonstrate that the integration of artificial intelligence substantially enhances the quality of digital exhibitions through the automated adaptation of interface design, visual content, and information presentation according to users' individual characteristics [12]. At the same time, the potential of AI extends well beyond personalization. Machine learning systems are increasingly employed for the automated description of museum objects, metadata generation, semantic analysis of collections, identification of relationships among cultural objects, and support for curatorial decision-making. These developments illustrate the growing role of AI as an analytical and interpretative tool capable of enhancing the efficiency and accessibility of museum knowledge management.

Nevertheless, the implementation of artificial intelligence also raises a number of significant museological challenges. These include concerns regarding algorithmic bias, the transparency of automated interpretative processes, the preservation of curatorial authority, and the ethical limits of delegating interpretative functions to algorithmic systems. In this context, artificial intelligence should not be understood as a substitute for museum professionals but rather as an instrument that supports scholarly research, collection management, and public communication. AI expands the institutional capacities of museums while simultaneously reinforcing the continuing necessity of professional humanistic expertise, critical interpretation, and ethical responsibility in the representation of cultural heritage.

One of the central propositions of contemporary digital museology is that virtual museums substantially expand access to cultural heritage. Unlike conventional museums, whose operation is

constrained by physical location, opening hours, and the material resources available to visitors, digital museums have the potential to provide continuous access to cultural collections regardless of geographical location, physical ability, socioeconomic status, or temporal limitations. From this perspective, the digitalization of museum practice represents an important mechanism for advancing the principle of cultural democracy by promoting broader, more equitable, and more inclusive public access to cultural resources. Moreover, virtual museums contribute to reducing long-standing barriers to participation in cultural life, enabling audiences that have traditionally been excluded from physical museum spaces – including individuals with disabilities, geographically remote communities, and socially disadvantaged groups – to engage more fully with both tangible and intangible cultural heritage.

Russia's full-scale invasion of Ukraine has posed an unprecedented challenge to the museum sector while simultaneously accelerating the transformation of the functions performed by virtual museums. Whereas, in peacetime, digital technologies were employed primarily to broaden public access to cultural heritage, under conditions of armed conflict they have acquired fundamentally new significance as instruments for documenting, preserving, and legally protecting cultural property. As a result, the digital museum has evolved beyond its traditional representational role and is increasingly becoming an integral component of the broader system for safeguarding cultural heritage.

In this context, the Ukrainian experience has assumed international significance. As Elżbieta Olzacka observes, from the very first days of the full-scale invasion Ukrainian museums implemented a wide range of measures aimed not only at the physical protection of collections but also at the digital recording of destruction, the documentation of war crimes against cultural heritage, and the creation of digital surrogates of artefacts and monuments at risk of destruction [13]. Consequently, digitalization has become not merely a technical process but also a form of cultural resistance and an essential instrument for preserving historical memory under conditions of war.

The scale of the challenge is further confirmed by UNESCO's assessments. By early 2023, the organization had documented damage to hundreds of cultural sites, including museums, architectural monuments, libraries, and religious buildings [14]. Under these circumstances, conventional mechanisms for the protection of cultural heritage proved insufficient, while digital documentation emerged as one of the few effective means of preserving information about cultural assets whose physical existence had been placed under immediate threat. Digital recording thus assumed not only a conservation function but also legal and evidential significance, providing reliable documentation for future restoration efforts, accountability processes, and international legal proceedings.

The Ukrainian experience has also demonstrated the emergence of a new category of digital museums whose primary purpose is not the presentation of existing museum collections but the documentation of lost, destroyed, or looted cultural heritage. One of the most illustrative examples is the *Museum of Stolen Art* project, which has established a digital archive of cultural objects destroyed or unlawfully removed by the Russian occupying forces [15]. Unlike a conventional museum, its exhibitions are organized around objects whose physical existence has already been lost or remains under imminent threat, while digital reconstructions serve as the only accessible means of preserving and publicly representing these elements of cultural heritage. This represents a significant conceptual shift in museum practice, whereby digital technologies function not simply as instruments of interpretation but also as mechanisms for preserving the memory of cultural loss.

A particularly significant example is the digital reconstruction of the Mariupol Drama Theatre, created using aerial imagery collected shortly before the building's destruction. The resulting three-dimensional model performs several complementary functions: it preserves the digital memory of a lost monument, provides a foundation for future scholarly research and potential reconstruction, and serves simultaneously as digital evidence documenting the destruction of cultural heritage during armed conflict [16]. In this respect, digital museums are becoming increasingly integrated into

international systems for documenting war crimes and protecting cultural heritage in accordance with contemporary international standards and practices. The Ukrainian case therefore demonstrates that virtual museums have expanded far beyond their traditional educational and exhibition functions, emerging as critical instruments of cultural resilience, historical documentation, and international heritage protection in times of war.

The war has also significantly intensified international cooperation in the field of the digital protection of Ukrainian cultural heritage. Large-scale three-dimensional documentation initiatives are being implemented through partnerships involving leading universities, international organizations, and specialized centres for digital archaeology. One of the most prominent examples is the *Our Land* project, coordinated by Archaic and CyArk with the support of the Jagiellonian University, the Iron Mountain Living Legacy Initiative, and other international partners [17]. The project aims to systematically document Ukrainian cultural heritage sites through high-precision three-dimensional recording, create accurate digital models, and ensure their long-term digital preservation within sustainable archival infrastructures.

UNESCO has likewise assumed a central role in these efforts by supporting the development of digital platforms for museum collections, providing Ukrainian institutions with specialized digitization equipment, and strengthening the digital infrastructure of the museum sector [18]. As a consequence, the digital preservation of Ukrainian cultural heritage is gradually evolving from a national initiative into an integral component of the international system for safeguarding cultural property. This process illustrates how digital heritage preservation has become embedded within broader frameworks of international cooperation, emergency heritage protection, and post-conflict recovery.

A distinctive feature of the Ukrainian experience is the gradual transition from isolated digitization projects toward the establishment of a comprehensive national system for recording museum collections. A key element of this process is the eMuseum platform, which functions as an integrated electronic register of the Museum Fund of Ukraine, providing access to object descriptions, digital images, and three-dimensional models of museum artefacts [19].

Unlike conventional electronic catalogues, eMuseum simultaneously performs several interconnected functions, including informational, scholarly, educational, communicative, and legal roles. The availability of a comprehensive digital passport for each museum object significantly facilitates its identification in cases of illicit trafficking, supports international efforts to recover stolen cultural property, and provides additional mechanisms for protecting museum collections during armed conflict. Consequently, digital registries have become not only instruments of collection management but also essential components of international cultural heritage protection and legal accountability.

Alongside the digital documentation of cultural heritage, another important direction in the development of virtual museums has emerged in Ukraine: museums dedicated to the memory of war. A notable example is the VR Museum of War Memory, which documents the destruction of Bucha, Irpin, Hostomel, and other localities in the Kyiv region [20]. Unlike conventional historical museums, whose exhibitions are typically created long after the events they commemorate, this museum develops its digital exhibitions almost simultaneously with the events themselves. Such an approach fundamentally alters the traditional temporal relationship between historical events and their musealization, transforming the museum into an active participant in the contemporary process of documenting history.

In this context, the digital museum performs functions that extend far beyond memorialization and education. It becomes a space for documenting collective trauma, constructing historical memory, and facilitating international communication about the consequences of war. The Ukrainian experience thus demonstrates the emergence of a new model of the virtual museum that combines the functions of a digital archive, a memorial space, a scholarly research resource, and an instrument of

international cultural diplomacy. This model reflects a significant expansion of the social and political roles of museums in the digital age, particularly under conditions of armed conflict.

Overall, Russia's full-scale invasion of Ukraine has substantially expanded the functional boundaries of the virtual museum. Alongside their traditional roles in exhibition, education, and the dissemination of cultural heritage, digital museums have assumed new responsibilities related to documenting war crimes against cultural heritage, preserving digitally reconstructed monuments, generating evidentiary records, and supporting international mechanisms for the protection and restitution of cultural property. This transformation represents one of the most significant developments in contemporary digital museology, demonstrating that virtual museums have evolved from platforms of cultural representation into essential infrastructures for heritage protection, historical documentation, and international cooperation in times of crisis.

Despite the evident advantages of the digital transformation of museum practice, virtual museums face a number of fundamental technological challenges, one of the most significant being digital obsolescence. Unlike physical museum objects, digital assets are highly dependent on software environments, data storage formats, and digital infrastructures. Changes in technological standards, the discontinuation of software support, the obsolescence of hardware, or the closure of digital platforms may render even properly digitized collections inaccessible over time.

In this context, the challenge of long-term digital preservation has become increasingly important. Digital preservation involves not only the creation of digital surrogates of cultural objects but also ensuring their accessibility and usability over decades despite continuous technological change. As recent research demonstrates, the creation, dissemination, and long-term preservation of digital cultural memory remain among the most complex challenges facing contemporary digital museology [3]. Consequently, the widespread perception of the inherent permanence of digital heritage requires critical reassessment, as digital resources are often more vulnerable to technological loss than the material artefacts they are intended to preserve.

An equally significant challenge concerns the establishment of an appropriate legal framework governing digital museum collections. The large-scale digitization of museum holdings has brought renewed attention to issues of copyright, related rights, ownership of digital surrogates, and policies governing open access to cultural heritage. In many instances, the legal status of digital representations of museum objects remains ambiguous, particularly in cases involving works that continue to be protected by copyright or possess complex histories of ownership and intellectual property rights.

The experience of leading museum institutions that have implemented open-access digital collection policies demonstrates that expanding public access to cultural heritage must be accompanied by the development of new legal mechanisms regulating licensing, attribution, citation standards, and safeguards against the commercial exploitation or manipulative use of digital representations of museum objects. Accordingly, digitalization is transforming not only the technological foundations of museum practice but also its legal and ethical framework.

One of the central conceptual dilemmas of contemporary digital museology concerns the relationship between maximizing access to cultural heritage and ensuring the quality of users' digital experiences. The most straightforward model of digital accessibility involves making photographic images of museum objects freely available online, thereby reaching the widest possible audience. By contrast, the development of fully immersive VR exhibitions, interactive three-dimensional models, or multi-user virtual environments provides significantly richer and more engaging experiences but requires specialized hardware, substantial financial investment, and an appropriate level of users' digital literacy.

Contemporary scholarship increasingly moves beyond presenting these approaches as mutually exclusive and instead advocates a multilayered model of digital accessibility, according to which

different modes of interaction should coexist in order to address the needs of diverse audiences and fulfill different communicative objectives [2; 3; 11]. Such an approach makes it possible to reconcile broad public access to museum collections with opportunities for deeper immersive engagement among users possessing the necessary technological resources. This layered strategy also reflects the broader principle of digital inclusion, recognizing that meaningful access to cultural heritage depends not only on technological availability but also on the diversity of users' capacities, expectations, and modes of participation.

Current developments in digital technologies indicate a gradual transition from the digital representation of museum collections toward fundamentally new models of cultural communication. One of the most promising directions is the integration of museum activities into the **Metaverse**, which enables the creation of persistent, multi-user three-dimensional environments unconstrained by geographical boundaries. Within such environments, the digital museum ceases to function merely as an electronic replica of a physical institution and instead acquires the status of an autonomous cultural space with its own exhibition formats, educational practices, and communicative ecosystems. An illustrative example is the Metaverse platform proposed for the presentation of traditional culture through the digital reconstruction of the Bells of Marquis Yi of Zeng, which demonstrates the potential of immersive virtual environments for preserving and interpreting cultural heritage [21].

An equally important driver of the continuing transformation of museums is the rapid development of artificial intelligence. At the current stage, AI applications extend far beyond the automation of cataloguing or collection retrieval. Artificial intelligence algorithms are increasingly employed to personalize museum experiences, generate metadata automatically, analyse large-scale museum datasets, design individualized visitor pathways, and adapt digital content to the educational needs of diverse user groups. As recent scholarship emphasizes, the integration of artificial intelligence opens museum collections to new forms of interpretation and interaction, making digital museums more accessible, inclusive, and user-centred while expanding opportunities for knowledge discovery and public participation [6].

Looking ahead, the convergence of the Metaverse, artificial intelligence, augmented and virtual reality, three-dimensional modelling, and digital archival technologies is likely to shape a new paradigm of museology. Within this emerging framework, museums will increasingly function as dynamic digital cultural spaces that integrate preservation, research, communication, education, and the collaborative construction of cultural memory. Under these conditions, digital technologies can no longer be regarded merely as auxiliary tools supporting museum activities; rather, they are becoming one of the principal forces driving the institutional evolution of the museum in the twenty-first century. This transformation signals a broader reconfiguration of the museum from a predominantly physical repository of cultural heritage into a hybrid, networked, and participatory institution capable of responding to the cultural, technological, and societal challenges of the digital era.

Conclusions. The findings of this study demonstrate that the virtual museum is not merely the product of the digitalization of traditional museum practice but represents a qualitatively new form of cultural space that fundamentally transforms the preservation, interpretation, and communication of cultural heritage. The evolution of the concept of the virtual museum – from a simple electronic catalogue to a multifunctional interactive environment – reflects the broader processes of digital transformation shaping contemporary culture. Within this context, the museum is increasingly evolving beyond the boundaries of a purely physical institution into an open, networked cultural space accessible irrespective of geographical location or temporal constraints.

The analysis of contemporary digital technologies has shown that the development of virtual museums is driven by the integrated application of three-dimensional (3D) scanning, photogrammetry, virtual and augmented reality (VR/AR), artificial intelligence (AI), digital platforms, and interactive

multimedia technologies. At the same time, the effectiveness of a digital museum depends not primarily on technological sophistication itself but on the quality of museological interpretation, the scholarly reliability of its content, and its capacity to facilitate meaningful engagement between users and cultural heritage. Technological innovation therefore constitutes a necessary, but not sufficient, condition for the successful development of virtual museums.

The study further confirms that the digital transformation of the museum sector creates significant opportunities for democratizing access to cultural heritage by making museum collections available to global audiences regardless of physical, social, or economic constraints. However, digital environments do not automatically eliminate existing inequalities; in many cases, they generate new forms of digital exclusion associated with uneven technological infrastructure, disparities in institutional resources, and differences in levels of digital literacy. Consequently, the continued digitalization of museums should be accompanied by comprehensive policies promoting digital inclusion and equitable access to cultural resources, thereby ensuring that technological innovation contributes to greater cultural participation rather than reinforcing existing disparities.

Virtual museums acquire particular significance under conditions of armed conflict. The Ukrainian experience clearly demonstrates that the digital documentation of cultural heritage performs not only memorial and educational functions but also serves as a crucial instrument for heritage preservation, international advocacy, and the documentation of crimes against culture. Virtual reconstructions of destroyed monuments, digital registries of museum collections, and international three-dimensional documentation initiatives have established a new domain of museum practice in which digital space functions as an arena of cultural resilience, historical memory, and international cooperation in the protection of cultural heritage.

At the same time, the growing adoption of virtual museums raises a number of fundamental challenges, including questions concerning the authenticity of digital representations, the long-term preservation of digital resources, copyright and intellectual property, technological obsolescence, and the ethical implications of artificial intelligence. These challenges underscore the necessity of developing new international standards for digital heritage preservation together with comprehensive public policies addressing the legal, technological, and ethical dimensions of digital humanities and digital museology.

Overall, the virtual museum should be understood not as an alternative to the traditional museum but as a new dimension of museum practice that substantially expands the possibilities for preserving, researching, interpreting, and disseminating cultural heritage. The most promising trajectory for future museum development is a **hybrid model** that combines the strengths of physical exhibitions with the capabilities of digital technologies, fostering openness, interactivity, inclusiveness, resilience, and long-term sustainability. As digital technologies continue to evolve, museums are likely to function increasingly as interconnected physical–digital ecosystems in which cultural heritage is not only preserved but also continuously reinterpreted, collaboratively constructed, and made accessible to diverse global communities. Such a model provides a robust foundation for ensuring the relevance and social impact of museums in an era characterized by rapid technological innovation and complex global challenges.

Use of Artificial Intelligence. No artificial intelligence tools were used in the preparation of this article.

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