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Enhanced Inclusion through Advanced Immersion in Cultural Heritage: A Holistic Framework in Virtual Museology

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Abstract: In recent years, the digitization of cultural heritage has been favored by significant advancements in specific technologies, such as photogrammetry and three-dimensional scanning. The digital representations of artifacts, paintings, books, and collections, as well as buildings or archaeological sites, has led to the transfer of cultural organizations to the digital space. On the other hand, the rapid development of immersive technologies and the Internet of Things is expected to decisively shape virtual cultural heritage in the coming years. However, this digital transition should expand its impact on most of the population. This article aims to cover the lack of structured methodology in the design and development of inclusive virtual spaces in cultural heritage. This research introduces a holistic framework that is mainly based on the disciplines of virtual museology. The proposed methodology takes into account the advancements in extended reality and the creative industry of computer games. The multisensory approach would lead to advanced immersive experiences, while the multilayered approach of cultural heritage content would enhance accessibility in inclusive virtual spaces. Moreover, this holistic framework could provide evidence from the virtual worlds that could be applied to real cultural heritage organizations.

Keywords: framework; virtual museology; digital cultural heritage; inclusion; immersion; virtual reality; multisensory; virtual museum; digital twin

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1. Introduction

Technology advancements have recently propelled the cultural heritage sector through a profound revolution with the Internet, interactivity, and hypertextuality, strengthening its dynamic transformative aspect. The embrace of technological innovations, from digitization to virtual reality (VR), adapted in dedicated frameworks, has changed the trajectory of the way the digital heritage landscape can be produced, interpreted, analyzed, preserved, and shared [1]. In this context, the cultural heritage sector envisages an evolution towards a more protected, inclusive, and long-lasting cultural content [2]. Furthermore, the digital transformation of cultural heritage has been significantly accelerated by interdisciplinary collaborations, resulting in increased reach and impact. In this vein, in the last few decades, several case studies of digital culture from different disciplinary perspectives have emerged, showcasing compelling evidence that multidisciplinary collaborations can lead to notable examples of the digital transition of cultural heritage, as Giordano et al. extensively outlined in their research [3]. This leads cultural heritage institutions to explore novel horizons in research, education, and engagement, spreading a new epoch of interaction and inclusiveness [4].

Although technological advancements have brought about revolutionary benefits to the cultural heritage sector, they also pose several complex challenges that require

careful consideration. The digitalization and virtual experiences raise questions regarding accessibility, authenticity, and sustainability. More specifically, there is a risk of widening the digital divide, as not everyone has equal access to digital devices or the required skills to navigate digital platforms. Digital experiences can heighten the risk of cultural appropriation or misrepresentation, thereby raising ethical and legal concerns related to ownership and copyright. Lastly, in the digital transformation era, the sustainability and environmental impacts of digital initiatives present challenges that should be considered in the preservation process.

Immersive technologies have experienced significant growth in recent years, and this is due to advances in hardware as well as the democratization of game engines [5]. In particular, the policy of the leading players in the field of game engines, such as Unity, Unreal, and others, has led to the rapid production of extended reality applications (XR), which offer innovative and impressive solutions in a wide spectrum of socio-economic life. In the field of cultural heritage in particular, augmented and mixed reality (AR, MR) solutions are turning visitors' smart mobile devices into useful tools for enriched guided tours of museums and archaeological sites [6,7]. Virtual reality applications offer remote access to collections and digital cultural spaces, while in several cases, the high level of immersion turns the user into the protagonist of unique experiences of history. However, the major challenge is the scalability that game engines offer to continuously incorporate innovative and emerging technologies such as artificial intelligence (AI), sensors, the Internet of Things (IoTs), haptics, and sense of smell [8]. On the other hand, the accessibility afforded by virtual worlds needs to be explored more extensively.

As the digital transformation pace of the cultural sector has accelerated significantly during the last decades, it has created new and wider opportunities for accessing cultural heritage. The digitization of cultural assets and their distribution through public repositories have made cultural capital accessible through widely used online platforms. Repositories enable the personalization of cultural experiences, given that the cultural content can be adjusted to the preferences, interests, and knowledge of the individual visitor, thus enhancing the inclusion perspective [9]. Nevertheless, as the digital solutions in cultural heritage become increasingly varied and diversified, it is crucial for these solutions to address the various ages, interests, skills, and expectations of the audience, as well as their cognitive and physical abilities. To address this challenge, cultural professionals foster more multisensory approaches and turn to the directions given by Universal Design Principles in order to make cultural content accessible and engaging to the largest possible spectrum of people. However, regardless of the progress that has been made, there is still a long way to go to further enhance accessibility and inclusion in cultural heritage.

This article introduces a holistic framework for even more inclusive and immersive user experiences in digital cultural heritage, through the interconnection of extended reality, the creative industry of computer games, and emerging technologies of haptics and olfactory, in alignment with the requirements of virtual museology. The remainder of this article is organized in the following way. In Section 2, the related work is analyzed, and the research aims and methodology follow. In Section 3, the holistic framework for enhanced inclusion and advanced immersion in digital cultural heritage is presented. In Section 4, a constructive discussion takes place, regarding the impact of the proposed framework in various perspectives, as well as the limitations that this research met. In Section 5, the article concludes with suggestions for future improvements.

2. Materials and Methods

This section depicts the state of the art in the main pillars of our research, namely (a) inclusive virtual museology; (b) advanced visualization technology for cultural experiences; and (c) creative industry of videogames and immersive technologies. This section concludes with our research aims and the methodology that was followed.

2.1. Towards Inclusive Virtual Museology

2.1.1. Virtual Museology: Requirements, Limitations, Perspectives

Virtual museology aligns with the new transformative dimension of digital museology, which requires a full-immersive user experience in a three-dimensional virtual environment without interaction with the physical environment [10,11]. Virtual museums (VMs) have emerged as a prominent pandemic response to remote access and new digital forms of engagement with cultural content, leading to beneficial interactions with space, objects, and learning motivation [12]. However, there is still a need for comprehensive research into frameworks that facilitate effective design, visualization technology, and storytelling methods [13]. This opportunity will enhance user interaction, emphasizing more the feeling of immersion and presence, notwithstanding the constraint of interacting with real cultural content [14,15]. Furthermore, the prospect of introducing new ways to interact by strengthening the modalities of both space and cultural content encourages user engagement, designing virtual experiences that are multisensory and multilayered [16]. While virtual museology has the potential to offer further accessibility, it is necessary to evaluate its reliance on virtual environments. It is crucial to ensure that virtual museums not only simulate physical spaces but also enhance the overall museum experience by incorporating the museological perspective that preserves the plurality and richness of a traditional museum experience and by featuring the cultural significance of the cultural content.

2.1.2. Related Frameworks for Designing Inclusive Digital Cultural Heritage Experiences

Over time, numerous frameworks and initiatives have been developed to promote inclusivity in the cultural heritage sector. The DynaMus framework draws cultural content from Europeana and Google to stimulate users to create personalized virtual exhibitions, fostering inclusivity by tailoring experiences to users' preferences [17,18]. MuseLearn provides multimedia content based on visitor profiles, overcoming cognitive and physical barriers to museum access [19]. The IntARSI project leverages multisensory immersive solutions to accommodate diverse audience needs and emotions [20]. WalkinVR pioneers accessibility in virtual reality, allowing mobility-impaired users to engage in virtual reality games [21]. The user-centric ArkaeVision project offers virtual representations, utilizing a 3D environment to generate inclusive and customizable cultural experiences [22]. The solutions developed for accessing and adapting the cultural experience can be accessed remotely, which improves accessibility for diverse audiences from a distance.

Moreover, these efforts not only highlight an innovative technological approach but also embrace a more conscious perspective of society towards inclusivity within the cultural heritage sector. Thus, the initiatives empower individuals from different backgrounds to actively participate in and contribute to several cultural experiences. The remote accessibility that these initiatives provide can extend the reach of cultural heritage to a wider range of audiences, fostering social inclusion and engagement regardless of geographical location.

2.2. Advanced Visualization Technology for Cultural Experiences

2.2.1. Visitor Behavior in Virtual Exhibition Experiences

Since 1928, visitor behavior in museum exhibitions has been an ongoing subject of multidisciplinary research, as it reflects the exhibition's multifaceted impacts on visitors' experience and assists curators in understanding the strengths and weaknesses of the museological design [23–37]. Respectively, with the emergence of digital and virtual museums, research interest has turned to the users' experiences, with the aim to comprehend the level of users' engagement with the virtual exhibition material or the visitors' feelings of satisfaction when experiencing digital or virtual environments. In more basic forms, like in the cases of simple, brochure-like online museums, the users' interaction with the 2D artifacts often fails to captivate attention or encourage learning [23]. However, the recent conjunction of virtual reality with museum practice has transformed the museum context by creating highly immersive and user-centered experiences that often resemble physical

museum spaces. Consequently, research on the users' motivation and the levels of engagement, learning, interaction, satisfaction, etc., in these virtual environments constructs a continuously updated core of study for the literature, which requires systematic and thorough study [38–44].

2.2.2. Digital Twins for Simulating Cultural Experiences

Digital twins can be described as digital copies of existing entities used to predict and adapt the performance of their real counterparts through data acquisition, analysis, and simulation. Digital twins' models have recently emerged as a helpful technological tool in the preservation of cultural heritage [45–49]. Yet, converting a physical cultural activity into its digital representation can also be a useful tool to analyze the behavior and experience outcomes of a museum visitor [48,50]. Based on the intention of understanding the interaction of space and human activity, the architectural tool *Space Syntax*, implemented in cultural spaces, produces simulations of human behavior that can assist curators in analyzing the exhibition layout related to visitor movement, sightlines, and interaction, and evaluating the exhibition's impact in terms of engagement and the meaning-making process [51]. Similar models can be applied to simulate user behavior in virtual environments. By utilizing digital twins for virtual spaces, creating digital counterparts of the performance of VR experiences, and analyzing human-centered activities through simulations, virtual environments can be tested and evaluated for their efficiency and sustainability [52].

2.3. Creative Industry of Videogames and Immersive Technologies

2.3.1. Game Engines

Leading companies in the creative industry of videogame creation often draw inspiration from history and cultural heritage to develop compelling and commercially successful products [53]. Their development takes place using a significant number of innovative experiments and results from the fields of three-dimensional (3D) graphics and artificial intelligence technologies within their laboratories. The platform on which such a complex product is developed is the game engine that every company owns and protects with industrial secrecy. On the other hand, the rally of competition that has taken place in recent years through the democratization between the two most widespread game engines has favored the rapid development of applications by small-scale companies and groups. In addition, game engines have already been used for the development of open and web-based authoring tools for stakeholders in education [54] and in cultural heritage [55].

2.3.2. Extended Reality

Under the umbrella of extended reality, applications have been developed in recent years for a better understanding, interpretation, and communication of cultural heritage with the general public. For example, augmented reality applications can offer enriched cultural walks in the center of a city or connect archaeological sites with their associated artifacts displayed in exhibitions or museum warehouses [56]. Virtual reality applications have the power to transfer the user to the historical context in which important events took place in virtual worlds [10] with a high level of immersion [57–59]. The adaptation and integration of haptic technologies into extended reality applications further increase the degree of users' immersion as the virtual world interacts with them in an expected and realistic way. Finally, efforts taking place in laboratories to integrate sense of smell into virtual environments are constantly strengthening and are expected to be a key component of extended reality applications in the coming years [8]. In any case, for the effective use of immersive technologies, they should be used in the context of interdisciplinary and apply appropriate frameworks for developing inclusive and accessible cultural experiences.

2.4. Research Aims

This article aims to address the following research questions, in the context of the suggested holistic framework for enhanced inclusion through advanced immersive experiences in cultural heritage, under the prism of virtual museology.

Q1: How could technological advancements contribute to designing immersive and inclusive cultural experiences?

Q2: How could advanced technological tools enable the comprehensive assessment of visitors'–users' museum experience?

Q3: How could interdisciplinary collaboration impact the evolution of virtual museology?

Q4: How could virtual museums offer more advanced immersive experiences?

Q5: How could inclusive and accessible virtual museums contribute to the more effective design of cultural experiences in the real world?

2.5. Methodology

The design of the virtual exhibition draws on the design principles and pipeline of physical exhibitions, on the grounds that a museological plan that encompasses the basic stages of perceiving the core exhibition idea, selecting the artefacts and arranging them according to a storyline, is an essential part of every form of exhibition. Nevertheless, the design flexibility provided by the virtual medium, as well as the inherited requirements or limitations, are being taken into consideration in shaping a virtual cultural experience. The preliminary phase of formatting a framework for designing an inclusive virtual museum consists of the following: (a) an overview of the related literature; (b) the users' needs configuration; and (c) the analysis of the key and advanced factors. Specifically, the first step is to conduct an extensive literature review and construct an up-to-date core of results that cover the subject from multiple and multidisciplinary perspectives. The second step is to define the target groups, engage with users' communities, and document users' needs. The target groups should represent the widest possible audience in terms of needs, capabilities, and preferences. The final step is to clarify the key factors as they emerge from the research and define the advanced factors that determine the conceptual approach of the design.

As there is a limited literature review on virtual museums, the framework applies the design principles of physical museums. Expanding upon this groundwork and promoting a multisensory approach in virtual museology, the key factors have been blended with the advanced factors. The methodology of the framework has been divided into three distinct phases so as to deal with the research requests. These include the (a) pre-production, (b) production, and (c) assessment phases. The initial phase consists of activities that must be completed prior to designing the virtual exhibition; the subsequent phase concerns the design of the 3D environment and the integration of cultural content; and the final phase focuses on the simulation of the users' behavior. The methodology is designed to enable the simulation and evaluation of each phase of the framework.

Extended reality technologies in themselves offer possibilities of inclusion but also a high level of immersion. With appropriate customizations, an application can be personalized to meet the needs of each individual user. In this direction, the proposed framework takes advantage of the additional capabilities offered by emerging technologies and integrates them into its holistic architecture. In this way, the framework is based on the multisensory approach, as it includes all senses, such as touch and smell, through the respective emerging technologies of haptics and scent. Another important element is that the recommended framework foresees the possibility of extensibility, as it is based on an open architecture that democratized game engines offer. Thus, the suggested methodology for the holistic framework ensures the design of a pipeline that would enhance inclusion through advanced immersion in cultural heritage, under the disciplines of virtual museology.

3. Results

It becomes clear that the challenges from heterogeneous fields need to be shaped into a holistic framework that will offer directions for designing and developing inclusive virtual museums. This section presents the structure of the suggested framework, including its ingredients and its main characteristics, as indicated in Figure 1.

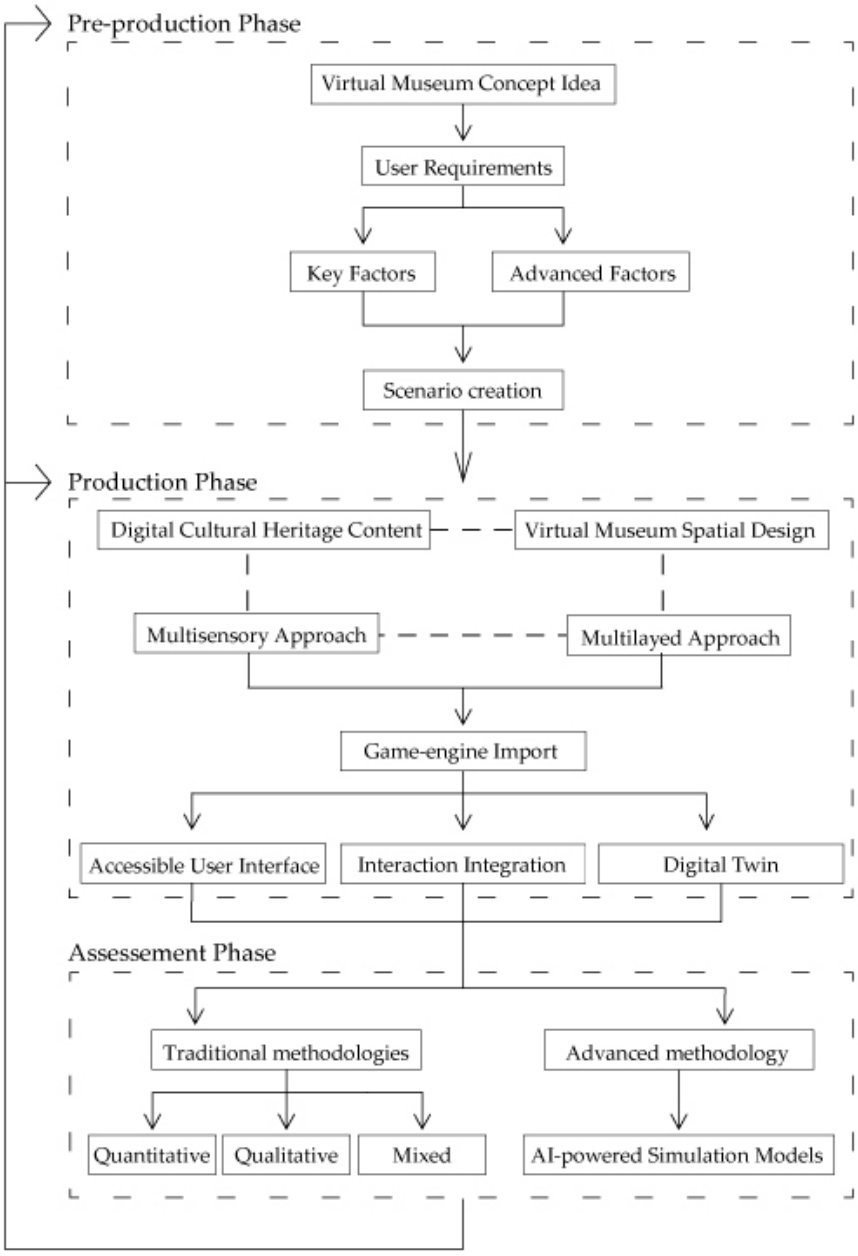

Figure 1. Conceptual framework of designing inclusive virtual museums.

3.1. Framework

3.1.1. Exhibition Concept Idea

The initial phase of designing an exhibition is to define the concept idea, a collaborative process that requires the contribution of all the disciplines involved. The process of shaping the concept idea of an exhibition starts with a combined analysis of the factors that have a definite role in the result. These are the exhibition material, the space, and the requirements according to the needs and preferences of the users. Based on these three factors, the curators outline the storyline and the objectives of the exhibition. The design of an inclusive

virtual exhibition requires the same configuration of the concept idea as in the case of a physical one, with the exception that it entails specifications regarding the user experience in a virtual environment and its inclusive perspective.

3.1.2. Exhibition Content

A pivotal determinant delineating this framework is that the proposed virtual environments emphasize experiences as opposed to objects. In the constrained time of a virtual experience, the selection of the digital cultural content should be made with care to complement the overall museum experience and effectively communicate the museological concept. Additionally, the various perceptual modalities of the exhibition content, serving as the means for communication between the audience and the virtual museum, should be prioritized. The framework benefits the transparent and open digital heritage data landscape, such as high-resolution 2D/3D objects, video, and hypermedia presentations that provide a high level of visualization and user interactivity (Table 1). Virtual spaces enable cultural assets that would be disincentive to display in physical exhibitions owing to space limitations.

Table 1. Types of digital cultural data that can be included in a virtual museum.

Digital Cultural Content Landscape	
Data	File type
Image	JPEG, PNG, TIFF,
Video	MP4, AVI, MOV
Text	PDF, DOC, TXT
Audio	MP3, WAV, AIFF, WMA, OGG
Interactive media	OBJ, FBX, gITF, JTL, USDZ/USD, STL, STEP
Metadata	Exhibit title, author/creator, description, year/period of creation, location, type of exhibit, dimension, material, license rights, related exhibit, source, references, etc.

3.1.3. Exhibition Spatial Design

Virtual museums are designed from scratch without restrictions, contrasting with physical museums. Nevertheless, the designer should maintain a connection with the museological space through ambiance, setting, and exhibit arrangement. Achieving the highest levels of engagement, immersion, and interactivity necessitates the effective design of virtual environments that cultivate users' comfort and familiarity. In the context of virtual museums, effective design can refer to the creation of a virtual environment that successfully fulfils the intended purposes while providing engaging, informative, and inclusive experiences to the users. Furthermore, the designed experience of a virtual museum should reflect the ambiance, layout, exhibition units, interactive features of the space, and displayed exhibits as in physical museums, as well as should make the users feel comfortable in the virtual space. Following the framework's principle, the architectural elements of the virtual exhibition should fulfill a specific purpose and function. The spatial design should be purposeful to support the narrative and evoke emotional reactions from users, enhancing the overall impact. The spatial design places emphasis on user flow, navigation, and orientation in order to ensure a seamless and beneficial user experience; thus, the inclusion of context, proportion, and scale facilitates the user experience throughout the virtual museum.

3.1.4. Key Factors for Designing Inclusive Virtual Exhibition

The key factors of the framework have been determined to address the challenge of designing inclusive virtual museums. These elements relate to both physical and cognitive

accessibility to cultural content through immersive experiences. The key factors, as indicated in Table 2, include the following: equitable use, usability, interactivity, multimodal perceptual approach, realism, educational perspective, and interdisciplinary. The framework proposes a guiding principle along with implicit directions for each key factor that the interdisciplinary team has to adhere to in order to facilitate the design process. In terms of cognitive accessibility, it is important that both the written and aural components of the virtual experience are concise and clearly comprehensible.

Table 2. The key factors determined in the framework for designing inclusive virtual exhibitions.

Key Factors for Designing Inclusive Virtual Exhibition	
Key Factor	**Framework Proposed Solution**
Equitable use	Principle: The virtual space should be designed to be user-friendly for an audience with diverse skills and perceptual modalities. Directions: • The designer should incorporate comprehensible instructions and effective support for users of all XR technology levels, ensuring a seamless overall experience. • The design should be useful, marketable, and appealing to all users.
Usability	Principle: The user interface should have functionalities regarding usability, allowing the audience to adapt it depending on their needs and preferences. Directions: • The users can customize the text layout (font size, background, color contrast) according to their needs. • The main architectural elements should also be adaptable to audience needs (e.g., color contrast, customized the designed text on the architectural elements). • Users should be allowed to decide and follow their own virtual exploratory plot. • The text included in the virtual experience should be legible and the audio comprehensive. • The users can customize the amount of information they receive according to their needs and preferences. • The design should provide adaptability according to the users' pace.
Interactivity	Principle: The museum design should include interactive activities to provide an engaging and attractive cultural experience. Directions: • The activities with which the audience can interact should be recognizable. • The interactive opportunities should be easy to understand and manage, offering simple and clear instructions. • The design of the activities should eliminate unnecessary complexity.
Multimodal perceptual approach	Principle: Any information integrated into the experience should be delivered through multiple media and sensory means. Directions: • Sounds, lights, colors, and lines (or other graphic aids) can be used to mark paths and interactive areas, help users identify points of interest, thematic units, and also help them orient themselves and navigate the virtual space. • Audio versions should assist with navigation and interaction activities. • The design should provide compatibility with a variety of means used by people with sensory limitations.
Learning perspective	Principle: The interactivity and learning outcomes that cultural virtual experiences offer facilitate memory making. Directions: • Meaningful integrated content stimulates learning motivation and triggers creativity, contributing to memory formulation.

Table 2. *Cont.*

Key Factors for Designing Inclusive Virtual Exhibition	
Key Factor	**Framework Proposed Solution**
Realism	Principle: The design should approach the highest possible level of realism. Directions: • Realism should concern the digital cultural content, the 3D virtual environment of the virtual museum, and its architectural settings. • The level of realism is interconnected with the level of engagement and enjoyment that a virtual museum aims to reach.
Cognitive accessibility	Principle: The content should address the needs, skills, and preferences of people with different levels of cognitive abilities. Directions: • The texts (whether in written or audio form) should be comprehensive, short in length, and easily understandable. • The content (interpretation material) should provide a clear hierarchy of information.
Interdisciplinary	Principle: The collaboration of interdisciplinary experts fosters the exploration of further opportunities for the effective design of inclusive virtual museums. Directions: • The exhibition design requires the collaboration and contribution of all the disciplines involved in the project.

3.1.5. Embracing the Multisensory Approach of Virtual Cultural Experiences

Recently, the multisensory approach seems to have gradually gained ground in digital culture, as diverse multisensory stimuli can make digital experiences more realistic and memorable [60]. Regarding virtual museology, the multisensory approach is an inherited element (Figure 2). On the one hand, virtual reality refers to a synthetically generated reality in which the visual, acoustic, and possibly tactile stimuli predominate to the point where they deceive the senses, convincing the user that they are immersed in an artificial, though highly realistic, world [22]. On the other hand, the museum experience itself is a multilayered journey consisting of proprioceptive, sensory, intellectual, aesthetic, and social facets [61]. Yet, by embracing the multisensory approach in virtual cultural experiences, the benefits refer not only to achieving more engaging results but also to widening the accessibility aspect to more diverse audiences (Table 3).

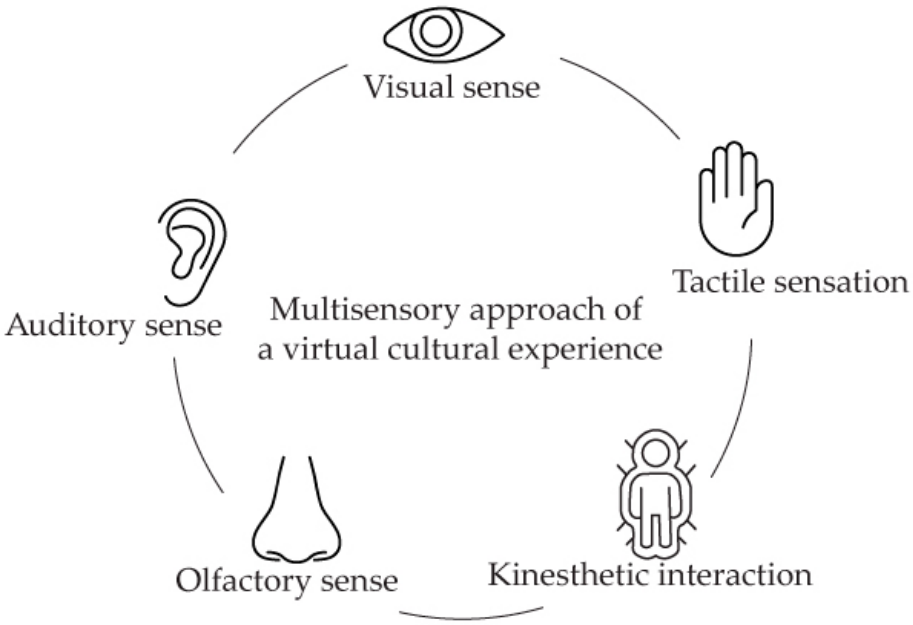

Figure 2. Multisensory approach of virtual cultural experiences [62,63].

Table 3. Interface features for accessible virtual cultural experience [22].

Accessibility Features in a Virtual Cultural Experience
Multisensory stimuli for navigation and orientation
Exhibit subtitles
Audio description
Multilingual content
Text-to-speech functionality
Adjustable font size
Color contract option
Flexibility in use

3.1.6. User Interaction and Engagement

Three levels of user interaction have been designed in the framework to achieve enhanced inclusion and engagement throughout the cultural experience (Table 4). The first level involves user interaction with the virtual space. The opportunity that virtual environments offer to integrate communicative media into primary architectural components for user interaction, along with sensory stimuli, serves to enhance immersion and cultivate multilayered experiences. The second level involves the exhibition units assisting in perceiving the conceptual context and promoting the learnability impact. The dynamics of stimuli that ignite various senses foster exploration and familiarity within the exhibition. The third level corresponds to artifacts. The user interaction with the exhibits and the different modalities embraced will evoke emotions and contribute both to the learnability process and the interpretation of the content.

Table 4. The three levels of user interaction that have been designed in the framework.

	Focus	Title	Objectives
Level 1	System-centric/ Architecture	Interaction with the virtual space	Highlight the link between virtual spatial design and virtual museum multisensory approach. Reinforcement of the overall multilayered virtual cultural experience.
Level 2	User-centric/ Experience	Interaction with the exhibition units	Perception of the conceptual context and promotion of the learnability impact of the exhibition. Effective for exploration and discovery activities.
Level 3	Content-centric/ Modalities	Interaction with the cultural exhibits	Enhancement of the learning process, contribution to cultural content interpretation. Emotional responses to elicit greater engagement.

3.2. Digital Twins for Museum Visitors' Behavior

3.2.1. AI-Assisted Dynamic Simulation of User Experience in Virtual Environments

Artificial Intelligence (AI) becomes increasingly applicable in the cultural field for documentation, conservation, and presentation purposes. Machine learning algorithms can analyze vast amounts of collected data and provide accurate simulations of the evolving behavior of cultural materials. This framework suggests the implementation of this concept for understanding users' experiences in virtual environments. The virtual counterparts of cultural sites, monuments, and museums require the engagement of users in multilayered and often multisensory interaction with tangible and intangible cultural heritage content, with the ultimate purpose of offering them a both entertaining and deep learning experience. An AI-assisted digital twin of a virtual experience can provide curators and designers with simulations of diverse users' behaviors based on variables regarding users' preferences, needs, and familiarity with virtual environments. Nevertheless, cultural activities engage people in multiple emotional and cognitive processes that may exceed the capabilities of current technologies in simulating human behavior. Critical and careful insights on the results of the applied AI technology in predicting and documenting the users' experience in

virtual environments may enlighten the inherited limitations and strengthen the validation of the results.

3.2.2. Monitoring and Assessment of the Virtual Environments' Engagement Power

So far, the performance of virtual museums is evaluated based on users' experience in terms of efficiency, engagement, and level of satisfaction, with the use of the more traditional evaluation methods based on user-centered design (UCD) [64–66] that enable the following remedial intervention on the original design. The lack of tools that autonomously obtain and process information reflects the existing gap in the use of AI-powered models in the evaluation process. By extension, the design and assessment of virtual environments, by monitoring the users' behavior in terms of interaction and engagement with their elements, may grant the efficiency, credibility, and sustainability of virtual environments beyond the effect of being impressed upon the first exposure to virtual reality.

3.3. Immersive Technologies

3.3.1. Application of Game Engine

The development of digital solutions that will use this holistic framework will primarily rely on the use of game engines. These development platforms offer the ability to include and collaborate with heterogeneous components through specialized plugins. Also, the game engines are accessible to all stakeholders who intend to develop virtual museums and virtual heritage spaces, due to their license policy. In addition, game engines offer the ability to generate real-time analytics related to user behavior. This feature creates new challenges by incorporating artificial intelligence elements to dynamically adapt the elements of the virtual museum to the personalized needs of the user. Finally, the development of virtual museums using game engines offers the option to export and distribute the final digital product on different platforms and architectures, as well as on universal web-based solutions such as WebXR. However, actual access to these tools may still be limited by factors such as the technical skills required to use them effectively, as well as the material and financial resources required to create quality experiences.

3.3.2. Application of Extended Reality

The holistic framework is based on extended reality and proposes the development of museums through virtual reality for four main reasons. First, virtual worlds can very accurately and consistently represent physical cultural spaces or even be built according to their specifications. Second, they can be supported by powerful computational systems to run user experiences smoothly. Third, they offer a high level of immersion to users as they are more isolated from real space through virtual reality devices. Fourth, they are characterized by a greater degree of inclusiveness for users, both because of their ability to represent information on multiple layers, and their capacity to interconnect and communicate with devices from emerging technologies, such as haptic and olfactory devices.

3.4. Emerging Technologies for Inclusive and Advanced Immersive Experiences

3.4.1. Application of Haptics

The building blocks of the virtual museum are either two-dimensional or three-dimensional representations of objects. They are characterized and recognized visually by their geometry and mesh, as well as by their texture and material. However, the integration of touch as a perceptual ability of the user in the virtual world would (a) increase the degree of user satisfaction due to the enhanced immersion in the virtual space for the sighted, and (b) enhance inclusion for people who have limited vision. The sense of touch could be rendered through haptic gloves, which could replace the controllers of the virtual reality device, fully integrating their functionalities. Additionally, the elements of digital representations themselves through textures and materials could be further explored to provide lighter 3D models in terms of geometry, but also useful information for haptic

devices about the texture of their surfaces. However, the integration of haptics in digital cultural heritage requires a thorough analysis of its practical, ergonomic, and perceptual implications. Thus, rigorous empirical evaluation is necessary to validate the impact of haptics in cultural heritage, as well as to ensure that technological advancements genuinely aim to improve the user experience in a meaningful and inclusive way.

3.4.2. Application of Olfactory

The more isolated from real space the users are, the greater the degree of immersion in the virtual world will be. The interaction with the virtual space becomes more realistic and convincing, especially when users engage all their senses. In this direction, the integration of olfaction is expected to offer advanced capabilities in applications that aim to achieve multisensory experiences of maximum immersion. The proposed framework encourages the development and integration of sense of smell into virtual cultural experiences as it can be hosted as extensible features of the game engine, while it could be combined with an easy-to-use and functional extended reality headset. In this way, users of virtual heritage sites could breathe the air of a coastal archaeological site, or a closed burial structure, while they could perceive the metal or wooden composition of the exhibits of a virtual museum.

4. Discussion

This section provides the space for further discussion towards the research questions of the article in alignment with the suggested framework. More specifically, the potential impact of the proposed framework regarding inclusive virtual museology, the assessment of the visitors' behavior, the necessity of interdisciplinary in virtual multisensory experiences, the advanced immersive applications in extended reality, and the knowledge transfer from the virtual worlds to real life.

4.1. Inclusive Virtual Museology

The exponential technological advancements towards immersive experiences have imposed a consequent adaptation in the cultural heritage sector. This research contributes to the effective design of inclusive virtual museums that leverage immersive technologies and the creative industry of computer games. In this context, virtual museums can be transformed into spaces that encourage broad public accessibility and engagement with interactive, multisensory content. The results of this study indicate that increased levels of sensorial experience integrations will facilitate a more seamless transition from a unisensory to a multisensory experience while also fostering a more holistic interpretation of cultural assets. Therefore, the evolution of emerging technological tools expands the opportunities for experience-oriented virtual museology, achieving multilayered cultural experiences.

4.2. Assessment of the Visitors' Behavior

A cultural experience that serves its objectives and offers visitors a meaningful and joyful time is the ultimate purpose and reason for the existence of an exhibition. Since the visitors' satisfaction lies at the core of an exhibition, its assessment and understanding of the elements that contribute to its success or failure to serve its purpose are of utmost importance. Recently, the utilization of technological tools has accelerated the level of accuracy of the results regarding visitors' behavior in physical exhibitions as well as users' experiences in digital/virtual ones. This paper suggests that the utilization of digital twins' models and AI algorithms for physical and virtual exhibitions [67–69] can strengthen the credibility of the design by demonstrating comprehensive insights on its efficiency beforehand.

4.3. Interdisciplinary in Virtual Multisensory Experiences

This study highlights that interdisciplinary plays a vital role in virtual museology, as evident in the proposed framework. From the perspective of creating inclusive virtual cultural experiences, interdisciplinary ensures a seamless blend of the physical and digital

realms, relying on the collaboration of museum professionals, historians, designers, and developers. This framework strives for a multisensory dimension to virtual museology by incorporating expertise from related disciplines, thereby surpassing the narrow emphasis on technology. Ongoing research on state-of-the-art issues will create new opportunities for collaboration to enhance the authenticity of digital cultural content as well as inclusion through advanced immersion. Therefore, by integrating supplementary layers of interactivity through a multisensory experience into virtual cultural spaces, the virtual museology landscape will become more multidisciplinary.

4.4. Advanced Immersive Experiences

An important functionality that virtual spaces offer is to be a field for conducting complex or specialized experiments from other research fields [70]. For example, by creating a convincing and photorealistic virtual museum, the users could be turned into research subjects to analyze and study their behavior under controlled conditions. In particular, by integrating an electroencephalogram device (EEG), eye tracking, and a wearable device, combined with game engine analytics, the users' emotions could be analyzed deeper, in relation to the environment and the exhibits they observe. This, in turn, could lead to conclusions about the optimization of virtual worlds. In this direction, the integration of technologies that maximize the user's degree of immersion in the virtual cosmos, such as smell and tactile interaction, could lead to exciting and inclusive experiences in the metaverses era.

4.5. Knowledge Transfer from Virtuality to Real Cultural Heritage Spaces

The physical sites of cultural heritage are primarily the basis for designing the virtual counterparts and for contributing with requirements/guidelines that can be adapted and integrated to virtual spaces. In reverse order, the proposed framework encourages the use of virtual museums as spaces for experimentation and deeper research into human behavior. The results from relevant studies in virtual environments could be transferred in the opposite direction and help to revise malfunctions and improve the daily functioning of physical cultural spaces. In other words, the knowledge transfer that will result from the application of the holistic framework could be applied to enhance inclusion in physical museums and archaeological sites. Especially considering the uncharted waters we are entering in the Metaverse era, the proposed holistic framework could act as a compass for the future design of virtual museums.

4.6. Limitations

The limitations of this study pertain to the users' needs for exploration and analysis, as well as a deficiency in evaluation. While the research aims to address the diverse needs and preferences of the users in designing an inclusive virtual museum, there is limited potential for a virtual museum to embrace the needs and preferences of the full spectrum of the varying users. Hence, a comprehensive mapping of the user needs and preferences of the target groups should take place prior to designing a tailored virtual exhibition. Although the proposed framework outlines a holistic methodology for designing inclusive virtual cultural experiences, it has not undergone evaluation yet. Therefore, it is essential to conduct subsequent and successive evaluations to assess the effectiveness, usability, and reliability of the framework in real-world settings.

5. Conclusions

This article proposes the preliminary and analytical design of a holistic framework that aims to enhance inclusion in the way virtual museums with a focus on cultural heritage are designed and developed. The framework exploits challenges from heterogeneous fields and emerging technologies, and under the principles of virtual museology, they are orchestrated to work for the benefit of end users through enhanced inclusion and advanced immersion

in virtual spaces that are multilayered and multisensory. However, the preliminary design of the holistic framework needs to be extensively tested in order to be validated.

As for future work, the holistic framework will be used for development, evaluation, and validation through the inclusive virtual museum of the MuseIT project. The results will also be used for further improvements in the architecture of the framework to maximize the level of inclusion, as well as to better interconnect the heterogeneous and multisensory aspects, for even more advanced and improved immersive experiences in cultural heritage. Furthermore, the holistic framework could and is expected to be applied in other fields, such as education and training.

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