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Capturing the Ephemeral:
A Framework Proposal for Saving Temporary Exhibitions in the Digital Age

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Digital Heritage and Multimedia

Supervisor **Prof. Sofia PESCARIN**

Co-supervisor **Dr. Marcello MASSIDDA**

Presented by **Laura TRAVAGLINI**

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ABSTRACT

Exhibitions have played a pivotal role in shaping our culture and history. Beyond mere displays of art, these events have functioned as platforms for scientific advances, revolutionary trends, political statements, and more, influencing the spirit of their times. Paradoxically, a notable scarcity of literature exists on exhibitions, with a collective memory loss concerning their importance and value. Once dismantled, the documentation of these meticulously curated endeavors, much as two centuries ago, is still primarily found within physical catalogues; limited and insufficient repositories, ill-equipped to capture the nuanced richness of these cultural spectacles. Hence, this thesis focuses on the exploration of preserving temporary exhibitions in the digital age by proposing a flexible and pragmatic framework to address this often overlooked goal within the cultural heritage field.

1 INTRODUCTION

1.1 Context

In 1863, the Royal Academy of Arts rejects approximately four thousand paintings for their annual Salon. In a matter of moments, the news reverberates, echoing all the way to the very ears of Napoleon III, who instructs that the rejected pieces be exhibited in venues near the Palais des Champs-Élysées¹. Beyond all expectations, the exhibition attracts nearly seven thousand visitors on its opening day, and May 15th, 1863, still resonates in the annals of art history as the Salon des Refusés bore witness to a radical shift in the perception of art.

In Émile Zola's novel "His Masterpiece", the reader can catch a glimpse of this seemingly chaotic event: lays between his lines all the confusion, humor, and bewilderment as the spectators encountered a new art that defied convention. The witty commentary and the mockery of the exhibited works simply mirrored the sentiment of the time, of an art world struggling to come to terms with the avant-garde. Yet, within this chaos, the seeds of a revolution were sown. A decade later, in 1874, these same denied artists, along with other talents like Renoir, Monet, and Degas, united with a shared vision of breaking free from the shackles of tradition and dictating their own artistic destiny. It was on this occasion that they held their first public exhibition, giving birth to a movement that would forever alter the trajectory of art history: Impressionism.

Throughout history, there have been many other significant examples that equally stood out as cultural milestones. From the Salon des Refusés and the birth of Impressionism to the 1937 "Degenerate Art" Exhibition, from the first Expositions Universelles to the contemporary Biennali and EXPOs: exhibitions, in their various forms, have played a vital role in shaping culture and ideologies, in defining eras. They challenged norms and left enduring marks on history, reminding us time and again that art, often unconventional, is a powerful force shaping our collective conscious. These events have not only showcased art but also served as stages for scientific discoveries, avant-garde movements, political statements, and more, as they portrayed and influenced the spirit of their particular eras.

¹ "Catalogue des ouvrages de peinture, sculpture, gravure, lithographie et architecture: refusés par le Jury de 1863 et exposés, par décision de S.M. l'Empereur au salon annexe, palais des Champs-Élysées, le 15 mai 1863", Bibliothèque nationale de France, <https://gallica.bnf.fr/ark:/12148/bpt6k114147v>

Surprisingly enough, they have been such prominent practices since just relatively recently, 250 years ago: “Exhibitions themselves are a new form, a later addition to the pantheon of classical forms such as drama, poetry, and rhetoric.” (Obrist, 2014). A form, indeed, an evolving art form in their own right, known as curating, with its own artists, the curators. Not mere assemblies of objects, rather temporal manifestations of artistic and intellectual endeavors, a convergence of ideas, artifacts, and interpretations interwoven for fleeting moments in time.

The art of curating proves to be an intricate craft, one that extend beyond the transitory act of selection, and just like the art they present, exhibitions call for projects of enduring significance, transcending what is superficial, or momentary: “Making art is not the matter of a moment, and nor is making an exhibition; curating follows art.” (Obrist, 2014). At least theoretically more than practically, as a daunting question remains, as documenting past exhibitions is still an open issue in the Museum Studies field: what becomes of the intricate orchestration and experience of an exhibition once it is dismantled? Where does its legacy reside?

As curator Hans Ulrich Obrist aptly notes, **“Curating, after all, produces ephemeral constellations with their own limited career span. There's relatively little literature on exhibitions, and there is also an extraordinary amnesia about exhibition history”**. So far, these meticulously curated tapestries of human creativity still find their memory, just as two hundred years ago, primarily entrusted to the pages of catalogues—repositories often ill-equipped to convey the nuanced richness of these spectacles. “An axiom”, to echo again Obrist (2014), “an exhibition is not an illustration”; on the contrary, as exhibition “can and should go beyond simple illustration or representation. They can produce reality themselves”. Restricting these multifaceted entities to such limited means, then, it is simply contradictory as it stifles their advocacy and the depths of their still underexplored potential, for the Cultural Heritage field and more generally speaking for our society.

Moreover, in a world where complex cultural events like exhibitions in their various forms are increasingly commonplace, there is a growing sense of “strong immunity” (Montanari & Trione, 2017) among the public. The inherent value and intricacy of exhibitions are often overlooked, and there is a registered absence of emphasis on the curator’s methodology, historiographical criteria, interpretive efforts, and the profound thought that goes into crafting their narrative (Montanari & Trione, 2017).

Many of these exhibitions have been reduced to mere spectacles, no longer serving as privileged mediums for facilitating in-depth and critical understanding of an artist's journey, becoming an end in themselves more than a means. And as exhibitions lose their role as platforms for deeper artistic purposes, also artworks, pivotal masterpieces of our history, are at times instrumentalized, brutalized. In Montanari's words (2017), "All these exhibitions are presented and marketed as 'dialogues', but true dialogue requires the capacity to listen and engage in meaningful discourse. And yet, the outcome is often a profound, isolating silence"².

Then, in the midst of this ongoing crisis within the realm of exhibitions, it becomes increasingly imperative to reflect and rediscover their cultural value, grapple with the multifaceted challenges they present and start concerning more comprehensively about their documentation. It is in this context and with this aim in mind, that the present thesis takes shape, seeking to explore the current state of the art in preservation techniques and the potential of evolving technologies, as they have been relatively underexplored in the context of preserving temporary exhibitions.

Aligned with the perspectives of scholars like Schweibenz and Scopigno, this research asserts the importance of virtually documenting past exhibitions and seeks to demonstrate how this can be achieved. They argue that:

Exhibitions take place 'within the curatorial and architectural framework created by the museum display', which is an artificial—if not to say a virtual—environment that constitutes the museum experience for the visitors. (Schweibenz & Scopigno, 2018)

This perspective proposes advocating for digitally documenting exhibitions with a focus on preserving not merely the physical objects, but also capturing their interpretative essence and their profound connection to the architectural space.

In the pages that follow, this thesis endeavors to explore how the digital domain can substantially enhance the preservation and presentation of fleeting yet profoundly impactful cultural moments such as temporary exhibitions, and to outline practical solutions exploring new technologies and their transformative potentials.

² Original text: "Tutte queste mostre, infatti, vengono narrate e vendute come 'dialoghi': ma per dialogare ci vuole la capacità di ascoltare, ed è necessario avere qualcosa da dire. E invece il risultato è invariabilmente quello di una terribile, muta solitudine" (Montanari & Trione, 2017).

1.2 Methodology and Thesis' Overview

In this section, I present an overview of the comprehensive methodology employed in this dissertation, which served as the foundation for understanding and addressing the multifaceted challenges of preserving temporary exhibitions in the digital age, seeking to bridge the gap between theory and practice. While discussing my research design, I am also going to rough out the structure of the thesis and what to expect from the next sections moving forward.

The three main steps of the methodology applied were: an initial and extensive literature review (Chapter 2), then a qualitative analysis through one-on-one interviews (2.1.2.; 2.2) and questionnaires (3, 4), and lastly, the consequent examination of all the data collected (3, 4).

Firstly, it was paramount to review the state of the art of the current preservation techniques employed for temporary exhibitions (2.1), the most recent efforts in the field (2.2.1; 2.2.3.), and the other relevant adjacent topics such as virtual technologies and XR platforms and tools for exhibiting art (2.2.2.). This investigation identified prior projects addressing the specific focus of this dissertation and critically assessed their strengths and weaknesses (2.2), to start building upon the insights gained the foundations of new, better structure solutions (3). I, then, managed to interview, experts who actively participated in the main initiatives taken into consideration in Chapter 2. This step sought to deepen the understanding of these projects, extract valuable perspectives, and uncover nuances otherwise difficult to grasp. These interviews were carried out in the context of my internships at CNR ISPC, the National Research Council - Institute for Heritage Science (Sesto Fiorentino, Italy), and Noho Ltd., a creative-know-how company specialized in producing digital experiences for a wide range of clients, particularly in the Cultural Heritage sector (Dublin, Ireland).

Experts were once again involved in a second activity, a qualitative questionnaire distributed online as a Google Form, both in English and Italian, where they were asked general questions about the exhibition design process, current practices, key figures and tools involved, as well as their own personal views on the future of exhibition conservation. Their responses were essential not only for understanding what is currently happening in the field beyond manuals, but also to move forward in my research. Although the response rate was not extensive, with around ten participants, it's important to emphasize that the depth and richness of the insights provided is nonetheless highly valuable, as all the experts come from a diverse and multidisciplinary group, with different academic backgrounds and expertise, and a wealth of experience. Specifically, the questionnaire

involved a curator, a professor, a technical producer, four researchers (Computer Graphics, 3D modelling, UX Design), a digital heritage creative specialized in Web Design, and a designer/front end developer.

By collecting, analyzing, and synthesizing data from these diverse sources, and stemming from previous notable examples, I was able to refine and outline an improved novel framework for the preservation of temporary exhibitions in the digital era, which is at the very core of this dissertation. The combination of literature review, expert interviews, and questionnaires facilitated a multidimensional exploration, contributing to highlight the main pain points and challenges of the process, propose solutions and strategies, and start assessing future scenarios and improvements.

Furthermore, it is essential to acknowledge the limitations inherent in this research methodology. As a university project and dissertation, this study faced obvious resource constraints, both economic and logistical in nature, which influenced to a certain degree its scope and scale, impacting the depth and breadth of data collection and analysis. Due to these constraints, the data collection process, as already mentioned, was primarily qualitative, and although attempts were made to involve relevant experts engaged in specific projects, this approach may not succeed in covering all the necessary aspects. Additionally, as a digital humanities' student, certain matters, such as economic and legal dimensions, especially in the context of the framework's discussion (3), extended beyond my expertise and the scope of this thesis. These limitations, of course, serve to highlight the need for future studies, drawing upon a broader range of resources and expertise. I firmly believe, nonetheless, that the presented research provides substantial insights, creating a basis for further examination into the digital preservation of temporary art exhibitions.

Given its implications in the ICT field, it is worth mentioning that, in the context of this dissertation, the formula “digital preservation”, employed at various stages, is used to signify the meticulous documentation and conservation of all aspects related to temporary exhibitions using digital means, and consequently the advantages of their applications.

Moving towards the conclusions of this thesis, a case study will be taken into consideration in Chapter 4. As the framework began taking shape, I had the chance to start testing and evaluating it in a practical activity. In the context of CHANGES, an ongoing PNRR national project, particularly within Spoke 4, the University of Bologna and CNR participated in a thematic sub-project dedicated to utilizing virtual technologies to promote, preserve, exploit, and enhance Cultural Heritage within museums and art collections. The primary focus was on a temporary exhibition

entitled “The Other Renaissance: Ulisse Aldrovandi and the Wonders of the World”, curated by the SMA, the University Museological System.

I contributed to the project in various capacities, among which the realization of a questionnaire involving the exhibition’s visitors. This activity provided additional valuable insights for my case study but also shed light on the perspectives of non-experts, whose opinions should not be underestimated as they represent the end users of these massive cultural efforts. In Chapter 4, detailing the whole Aldrovandi’s case study, I have also presented in more detail a prototype for the virtual replica, which I was heavily involved in, and explore expected future developments and scenarios of the CHANGES’ project.

2 STATE OF THE ART

2.1 Current Preservation Techniques

Despite notable technological advancements and promising initiatives in the field, there persists a sense of cautiousness and hesitancy toward embracing digital solutions for the preservation of temporary exhibitions within the current/contemporary Cultural Heritage landscape. As a matter of fact, a close examination of the practices employed by the world's most influential cultural institutions reveals that their efforts in this area are frequently limited to dedicating a single web page to showcase their past exhibitions. Generally, these websites offer little information such as a simple overview with dates, a link to buy the catalogue, and hardly ever a few images and supplementary content. It is also surprising that a few extremely prestigious institutions, such as the Vatican Museums, the Tate Modern, and the Humbolt Forum amongst others, fail to display even these basic details, highlighting the lack of comprehensive preservation strategies.

Table 1, below, presents the top 20 museums globally based on the 2022 annual report by The Art Newspaper, the *Visitor Figure*³, a renowned authority in the field of art and culture. For each museum listed, I have also assessed whether they maintain a dedicated section on their website for archiving past temporary exhibitions, and in the final column, I have included the timeframes accessible within their archival documentation array, offering additional insight into the scope of their dedication.

Museum	City, State	Past Exh. Page	Documented Years
Musée du Luvre	Paris, France	Yes	2019 - 2023
Vatican Museums	Vatican City	No	-
British Museum	London, UK	Yes	2018 - 2023
Tate Modern	London, UK	No	-
National Museum of Korea	Seoul, South Korea	Yes	2018 - 2023
Musée d'Orsay	Paris, France	Yes	dossiers of 4 selected exhibitions
National Gallery of Art	Washington, DC	Yes[1]	1941 - 2023
Metropolitan Museum of Art	New York City, NY	Yes	1999 - 2023
Centre Pompidou	Paris, France	Yes	1977 - 2017

³ <https://www.theartnewspaper.com/2023/03/27/the-100-most-popular-art-museums-in-the-worldwho-has-recovered-and-who-is-still-struggling>

Museum	City, State	Past Exh. Page	Documented Years
State Hermitage Museum	St Petersburg, Russia	Yes	1997 - 2023
National Gallery	London, UK	Yes	2007 - 2023
State Russian Museum	St Petersburg, Russia	Yes	1999 - 2023
Museo Nacional del Prado	Madrid, Spain	Yes	2003 - 2023
Victoria and Albert Museum	London, UK	Yes[2]	1999 - 2015
Somerset House	London, UK	Yes	2008 - 2023
Galleria degli Uffizi	Florence, Italy	Yes	2009 - 2023
MoMa	New York City, NY	Yes	1929 - 2023
M+	Hong Kong, China	Yes	2016 - 2023
National Museum of Scotland	Edinburgh, UK	Yes	2022 - 2023
State Tretyakov Gallery	Moscow, Russia	No	-

Table 1, top 20 museums worldwide (2022) and their website's page archiving temporary exhibitions.

n.	Table's notes
[1]	Available online list of all the past exhibitions held at the Corcoran Gallery of Art from 1897 to 2014.
[2]	V&M has an additional/external website (still in its beta version) dedicated to exhibitions only - current, upcoming and past: https://www.newexhibitions.com/gallery/617 . The past exhibitions documented go from 2000 to 2023.

It is noteworthy that institutions do retain information about past exhibitions within their own private archives or databases, albeit inaccessible to the public. Consequently, while the backend techniques for retaining such data may vary, the most common and available means for accessing this information remains the basic single web pages mentioned earlier. And, as of 2023, the predominant tool used for preserving past temporary exhibitions' legacy and essence remains rooted in physical catalogues.

“No exhibition of any pretension is complete without lasting proof of its existence, preferably in print on coated paper” writes art critic Michael Glover still in 2020, and, indeed, the role of catalogues in art history literature continues to be fairly significant. They contain not only the core documentation and new scholarly productions related to the shows and their displayed items, but can also still influence the fame of certain artists or curators involved in their writing (Glover, 2020). At least on a theoretical level, these publications keep serving their primary purpose of education and knowledge dissemination as valuable resources (however mainly) for scholars, researchers, and art enthusiasts. By definition, though, a “Good catalogue” should also convey

“Something of the flavor, the temper, the attitude, the very feel of the show, while revealing something important to us about the nature of its subject” (Glover, 2020). In practice, the execution and fulfillment of this mission may become more complicated and may not be entirely carried out. Therefore, it is crucial to consider its limitations in achieving this.

“Superb, but misleading catalogues”, states Haskell (2000) in his comprehensive work about exhibitions, *The Ephemeral Museum*. “Incomplete and unbalanced” (Haskell, 2000) he continues. Because, although organic and rich in detail, they are not sufficient to capture the multifaceted nature of temporary exhibitions.

Firstly, being inherently two-dimensional, their contents are bound to text and still images, quite reductive materials when compared to the essence and meaning of an actual exhibition. The space allowed by the volume may also dictate the amount of information included, shrinking the already limited content presented. Additionally, these catalogues are, by definition, *a priori* works, created and completed way before the exhibition takes place: this makes it basically impossible for these means to illustrate the actual event, excluding all the information about the experience, the audience, the display, and the aftermath. As a result, they lack the ability to capture the more salient features of such complex cultural events, their visual spectacles, compelling narratives, spatial and social intricacies, their essential curatorial insights and innovative museological approaches, their potentially immersive aspects that truly define the exhibitions themselves (Haskell, 2000). Furthermore, their accessibility is generally hampered by the need to pay, limiting their reach to a selected and scarce audience.

2.1.1. The OSCI Framework

At this point, it is necessary to examine the future of these methods considering their just acknowledged inadequacies. However, it is crucial to consider other factors beyond the ontological limitations mentioned earlier before answering or, better, exploring this issue in more depth. These additional elements may provide added insight as to why time is running out for catalogues.

In the early 2010s years, the convergence of several key variables was already starting to be observed, including recession-related budget cuts, high production costs, and low demand for

catalogues⁴, and the first significant technological advances. Numbers were not left unnoticed and institutions came up with different solutions in no time. Certain established institutions like the Metropolitan Museum of Art modified their approach and while they remain committed to producing scholarly exhibition catalogs, some were scaled down compared to the past due to cost considerations. Alternatively, other institutions, such as the Los Angeles County Museum of Art (Dobrzynski, 2010) for example, started to assess each exhibition on a case-by-case basis and consequently chose for alternative strategies. Also, given the sudden rise of new means and technologies such as the first e-books and e-readers, they started pondering between traditional printed catalogs, online versions, or print-on-demand formats.

As a result, online catalogs were immediately identified as possible satisfactory and more convenient and easy-to-manage options. However, as soon as they began to be put in place new challenges emerged - image copyright permissions and difficulties in monetization among many others. Nevertheless, institutions persisted in adapting while experimenting with these new models, and technologies. The shift toward digital was already underway.

In this context, major players in the art system and industry started undertaking the first organic efforts. In 2009 the Getty Foundation in partnership with the Paul Getty Museum and eight other participating museums joined forces to launch OSCI: the Art Institute of Chicago; the Arthur M. Sackler and Freer Gallery of Art; the Los Angeles County Museum of Art; the National Gallery of Art, Washington, D.C.; the San Francisco Museum of Modern Art; the Seattle Art Museum; Tate; the Walker Art Center.

The Online Scholarly Catalogue Initiative (OSCI) was a pioneering project aimed at transforming the way art institutions present and share information about their collections and exhibitions. The initiative focused on reimagining/bridging the gap between traditional catalogs and scholarly publications in the digital age with the primary goal of creating a standardized framework for developing online scholarly catalogues, enhancing accessibility, interactivity, and engagement with art and cultural content. By doing that, OSCI addressed the evolving needs of museums and audiences by harnessing the potential of digital technology, encouraging them to move beyond static printed catalogs and embracing dynamic online platforms. These digital catalogues provided

⁴ According to estimations done in 2019, for instance in Italy, the redemptions (the ratio between visitors and sold catalogues) was getting wider, being at that time around 1 to 20. https://milano.corriere.it/19_marzo_28/laura-regina-bookshop-grandi-mostre-vestale-dell-arte-formato-pop-af7e0d3e-5131-11e9-a893-b193ce6f4a88.shtml?refresh_ce-cp

opportunities to integrate various media forms, such as high-resolution images, videos, interactive elements, and multimedia presentations, enhancing the overall visitor experience.

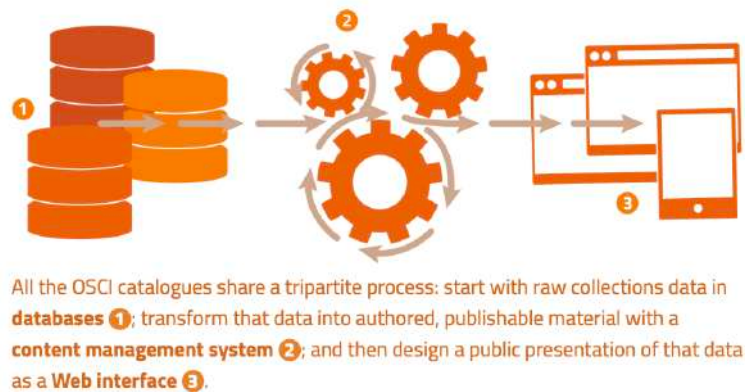


Figure 1, Visual representation of the OSCI Framework, source: OSCI report.

Throughout the project, three main approaches were identified and institutions were free to choose the one that best suited their needs. The first focuses on the integration of catalogue publications/embedding of scholarly content within existing museum websites, improving accessibility and linking to other resources. The second advocates dedicated stand-alone platforms that prioritize specialized content presentation and dynamic user experiences. And the third approach explores a decentralized model where content modules are distributed across multiple websites, allowing for focused content creation and integration into different contexts.

Beyond the various outcomes and successful projects that emerged from the initiative, the OSCI framework was overall a paramount milestone for digital transformation/transition in the Cultural Heritage field. Although the initiative ended in 2017, there is still much to be learned from it/its lessons are still to keep in mind/there are still major takeouts to keep in mind moving forward.

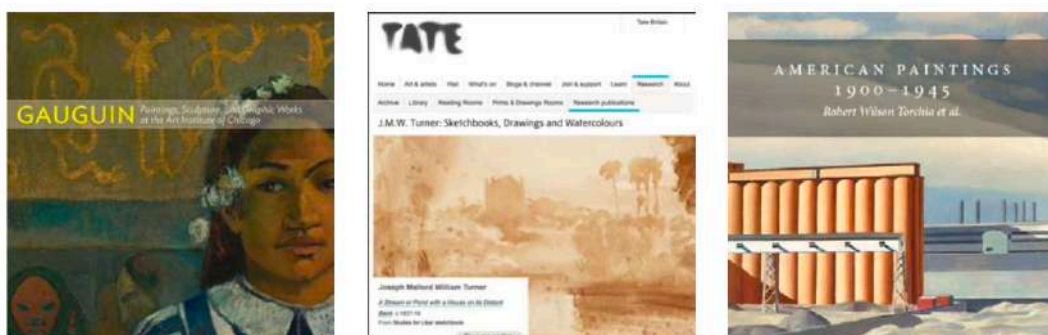


Figure 2, Examples of museums that have successfully continued publishing online catalogues using their OSCI systems and workflows; from left to right: the Art Institute of Chicago, Tate, and the National Gallery of Art.

Main lessons learned have been:

1. Digital publishing necessitates cross-collaboration, contrasting with traditional linear team modalities. As a result, a multidisciplinary approach combining curatorial expertise, technical knowledge, and design skills is fundamental. To merge all the requirements and allow effective collaboration, a functional requirements document is indispensable. In this complex collaboration, stakeholder engagement (including curators, educators, and technologists) ensures a comprehensive and well-informed approach. These elements, in conjunction with the selection of the right technologies, also guarantee that innovation is fostered and alignment with institutional identity and mission is ensured.
2. Technologies are to be chosen wisely, according to the institution's needs and ambitions, and after the assessment of the ones already/currently in use;
3. Adequate funding for technology infrastructure, ongoing maintenance, and content creation are paramount for these kinds of projects;
4. Ongoing maintenance planning is not to be underestimated in the digital realm also long-term preservation-wise;
5. Data standardization is needed to strike a balance between consistency and adaptability;
6. An extra focus must be reserved for user experience and accessibility of data: Online audiences are new and variegated (for example, the NGA followed the skim - short synopses for general reader -, swim - further information for curious amateur -, dive - rich content for the scholarly researcher - approach to address more users at the same time); Content should be accessible and downloadable;

Remaining challenges to be addressed, on the other hand, include:

- How to make the online catalogue more visible and easier to find only, so how to optimize its discoverability (SEO optimisation);
- How to ensure long-term preservation;
- How to ensure sustainability.

Most importantly, it was exactly during these years and with the advent of these specific initiatives that cultural institutions first came to terms with what Maria Hlavajova, director of BAK (Basis for Aktuell Kunst) in Utrecht, called the “zero visitors policy”. What she intended to emphasise with this expression was not the lack of physical visitors, but rather the newfound potential to engage with an audience beyond the establishments’ physical boundaries. As the new fruition of the internet was without a doubt transforming the notion of a museum's audience, these institutions had to expand their outreach and digital presence, fundamentally reconsidering their relationship with

their audience online. Furthermore, as a consequence of this digitization trend among museums, the transparency they had been required to embrace to establish a sense of responsibility and openness was shaping the manner in which they represented themselves, ultimately leading to a deep self-reflection in the process.

This should be an example for the way museums consider their activities online: to conceive of the internet not as a tool to cancel the geographical constraints of what is considered to be a museum's traditional audience, but as a space in which a museum can participate in larger conversations that relate to its mission. (Gat, 2015)

And it didn't take long for institutions to find themselves solely depending/heavily reliant on these remote means when geographical limitations became a reality in 2020. Museums and galleries, drawing on these past years of early experimentation with digital platforms, responded promptly to the exceptional contingency of the pandemic with varying degrees of success and innovation to mitigate its impact. Despite this apparent swiftness, the arts and culture sector faced particular challenges during this transition. Unlike other art forms like music and cinema, which adapted more easily to the digital environment, the Cultural Heritage field indeed required more time and effort to provide digital alternatives for experiencing exhibitions and artworks. While the necessary technological infrastructure was already available, high costs, concerns about long-term visitor engagement, and the attachment to in-person art experiences firstly inhibited a shared and effective response in the Cultural Heritage field (Amorim & Teixeira, 2020).

2.1.2. COVID's Main Initiatives and Gained Perspectives

"I was never in favour of going online; I thought it distracted too much from the gallery. But now that I'm working from home it has my full attention and I'm embracing it. We had hundreds of people engaged from the first day," admitted the famous gallerist Thaddaeus Ropac to the Art Newspaper, right after launching the gallery's first online viewing room in March 2020. Many institutions followed suit, turning to digital platforms, streaming services, and virtual reality to engage with audiences and continue their activities.

Nothing extremely grand breaking was registered, as relatively niche technologies like virtual reality (VR) and immersive media simply began to experience renewed interest and growth. Interestingly enough, this resurgence aligned with the prediction made in 2015 by immersive artist,

entrepreneur, and director Chris Milk, who suggested in a famous TED talk that virtual reality could become the "ultimate empathy machine" (<https://www.youtube.com/watch?v=iXHil1TPxvA>).

In a world that had never felt more physically isolated, digital media started to act as a cultural bridge, offering a diverse range of experiences, such as live-streamed performances like the ones of the Metropolitan Opera and the Cleveland Inner City Ballet, or virtual tours of museums and other institutions, like the Met 360 Project (<https://www.metmuseum.org/art/online-features/met-360-project>), but also outdoor places like a virtual walk through the New York Botanical Garden's spring bloom-scape (<https://www.nybg.org/planttalk/take-a-virtual-walk-through-nybgs-spring-landscape/>).



Figure 3, Overview of digital initiatives in Europe during COVID-19, source: Europeana Pro.

A major player in this transition was undoubtedly Google Arts & Culture (<https://artsandculture.google.com/>), which, since the pandemic, partnered with over 2000 organizations from 80 countries to connect them with their audiences, provide access to over seven million artworks in high resolution, create virtual experiences, and more on just one platform, and for free. Some notable examples include:

- An ambitious campaign that, in Vienna, put almost all the city's cultural treasures online, from the Belvedere (<https://artsandculture.google.com/partner/belvedere>) to the State Opera, which currently offers selections from its archive of video performances as well as a VR/360-degree experience (<https://yourstage.wien.info/en-us/article/staatsoper>), recently gaining 130,000 new registrations on the opera's streaming platform and apps;
- A virtual trip to the Van Gogh Museum, in Amsterdam (<https://artsandculture.google.com/partner/van-gogh-museum>), which made available one of 17 collections of Van Gogh paintings, including sunflowers, self-portraits, and his famous "The Bedroom";
- A virtual tour of the Uffizi Galleries in Florence, Italy, (<https://artsandculture.google.com/story/cQVh5Rbqa2Q3dg>), featuring up-close looks at the museum's interiors and the stunning masterpieces, including Michelangelo's "Doni Tondo" and Botticelli's "The Birth of Venus";
- A selection of modernist triumphs inside the Guggenheim Bilbao Museum in Spain (<https://artsandculture.google.com/story/gAUBcl7HrOX7LA>);
- A digital walk through the Smithsonian American Art Museum's "African American Art: Harlem Renaissance, Civil Rights Era and Beyond" photography exhibition (<https://artsandculture.google.com/story/NQXxo3o0fCnXJg>) featuring work by black artists from the 1920s through the 2000s;
- The new study of Frida's clothing and accessories realized by the Museo Frida Kahlo, in Mexico City, now accessible through a digital view titled "Appearances Can Be Deceiving: Frida Kahlo's Wardrobe" (<https://artsandculture.google.com/story/rAUBPDLcNAzkJA>);
- Art Zoom videos, sort of mini-documentaries, zeroed in on tiny details of famous canvases and narrated by famous musicians including Jarvis Cocker and Maggie Rogers (an example: Pieter Bruegel the Elder's "Tower of Babel" as examined by Feist, <https://www.youtube.com/watch?v=aRodeuCGEUs&feature=youtu.be>).

The emergency, thus, proved to be a catalyst for transformative change in the art world, pushing institutions and galleries to explore the untapped potential of the digital realm. "Before Covid-19, the digital space was almost always treated as an afterthought for expanding an audience beyond the reach of physical spaces," commented JiaJia Fei, Digital Strategist and Consulting Director of Digital at the Jewish Museum in New York. Galleries like David Zwirner and Pace Gallery have as well witnessed a surge in digital interest, emphasizing the unique advantages of online exhibitions. "Online exhibitions can do things that brick-and-mortar exhibitions can't," declared the head of content Lucas Zwirner. "They can embed videos, longer excerpts of art-historically relevant

material, and artist-created content”. And again, on this same matter, Natasha Arselan, founder of AucArt, an online sales platform that represents more than 100 emerging artists, thought about the new opportunities arising as she said in a contextual interview to The Art Newspaper:

People have been undermining the experience of viewing art online for years and are now flocking to it. [...] They realise it is not a replacement for the real thing but it’s still a valid experience that adds a huge amount. It’s all about a different sort of creativity right now.

Unfortunately, though, despite the pandemic accelerated the uptake of virtual participation, these initiatives were never fully integrated into sustained efforts when the emergency loosened up. In the context of this dissertation, it is important to note that they were specifically never utilized to digitally conserve and present past temporary exhibitions within the wider cultural context. Rather, they frequently served as time-limited illustrations, primarily addressing emergencies with restricted follow-up investigation.

However, an exception emerged among profit-oriented entities within the cultural sphere, particularly contemporary art galleries, which distinguished themselves by maintaining structured and accessible online records and archives of their past exhibitions even after the emergency. This proactive approach can, most likely, be attributed to their profit-driven nature, which incentivized them to showcase comprehensively and online their activities.

In the unique circumstances of the pandemic, they swiftly recognized the advantages of establishing a robust online presence, making a wealth of information accessible to their clientele. It extended beyond mere engagement, as observed in non-profit initiatives (such as, for example, the massive deployment of live-streaming platforms such as Twitch and YouTube), encompassing a thorough collection, curation, and subsequent presentation of data in new manners. By doing so, these galleries expanded their reach to a broader audience and adopted more effective marketing strategies. They started investing in sophisticated Customer Relationship Management (CRM) systems not only to present a comprehensive archive of their artistic endeavors but also to launch deliberate campaigns potentially marketing the artworks within their collections.

It must be noted, then, that this strategic use of digital tools for conservation and, notably, promotion of their temporary exhibitions underscores how economic considerations and an acute awareness of digital trends have propelled galleries to develop refined digital preservation tactics. To put this in perspective, while online art sales remained relatively static in 2019, before the pandemic, the first half of 2020 alone witnessed astounding revenues. Christie's, Sotheby's, and

Phillips collectively posted revenues of USD 370 million during this period, marking a staggering increase of over five times compared to the same period in 2019. These developments go beyond the realm of auction houses. For a significant majority of industry operators, galleries are poised to become pivotal players in the online art world in the near future.

During my internship at Noho, I had the opportunity to discuss the impact of the pandemic on the art business with Tara Murphy, director and owner of the Solomon Art Gallery (<https://www.solomonfineart.ie/>) in Dublin, Ireland. Over her extensive career in the field, she has observed the evolution of preservation techniques from basic archiving methods to the diverse range of documentation that is now available for public dissemination. The pandemic has merely accelerated this already ongoing trend.

In the midst of this crisis, Ms. Murphy, like many of her peers, recognized the need to maintain a strong online presence in order to reach clients, and as a solution, she opted to use Artslogic (<https://artlogic.net/>), a popular UK-based database that has developed over the past few years into a fully customizable CRM system. This allowed Tara to showcase current exhibits and her inventory to potential clients, which resulted in the busiest year on record for the Solomon Art Gallery, thanks to the increased visibility provided through Artslogic. Even post-pandemic, Artslogic remains a relied-upon system due to its impressive management of high-resolution exhibit photographs, downloadable PDFs of exhibitions' catalogues, virtual viewing rooms for artworks, and an artist and news sections, with all the materials documenting each exhibition's aftermath (reviews, articles, etc.) and various links to additional and sometimes external content.

2.1.3. Focus on Italy

Before moving forward and in order to provide a more comprehensive overview of the currently implemented techniques, it is imperative to include information from other regions as well. For the purpose of this dissertation, I will now examine Italy's case and initiatives from the pandemic to the present days.

During the health emergency, Italy, as the “cradle of Art and Culture”, tried its best not to stay behind as national museums, art galleries, and foundations made their own personal effort in staying connected with the public during the lockdown. Answering the call of *#iorestoacasa*, *#museichiusimuseiaperti* and *#laculturanonisferma*, these cultural institutions have turned to social

media to promote their collections and engage with the audience through virtual initiatives. The digital programs range from exploring archives and museums remotely to providing art lessons for children, demonstrating how art and culture can be accessible from anywhere, at any time. Additionally, Italy's Ministry for Technological Innovation & Digitization (MID) and the country's digital agency (AgID) collaborated to create a Digital Solidarity Site (<https://innovazione.gov.it/argomenti/solidarieta-digitale/>), offering various free cultural services to citizens, including magazine subscriptions and online courses, aimed at mitigating the effects of the pandemic.

In this context, an exemplary role has been undertaken by Centrica, a company specializing in digital solutions for cultural organizations, which with its innovative projects, such as the “Renaissance Experience: Florence and Uffizi” (<https://vimeo.com/257208503>) and “Uffizi Touch Cloud” (<https://vimeo.com/189537541>) have greatly contributed to the cause. This company, even before the pandemic, developed the ArtCentrica cloud application with the aim of bringing art into schools and universities, aiming at the democratization of art fruition, evolution of art teaching and learning methodologies, and the production of new business models that increase museum earnings. ArtCentrica has allowed the user to have access, in a simple and engaging way, to more than 1,250 works, through digital images - in very high resolution - belonging to the collections of the Uffizi Galleries and the Pinacoteca di Brera.

Focusing now on the present national landscape, Italy's approach to digital preservation aligns with global practices. However, it is noteworthy to examine specific national initiatives, their applications, and limitations. Stemming from the 2011's ministerial guidelines “Mostre virtuali online. Linee guida per la realizzazione”, Italy embarked on a collaborative endeavor between enterprises and institutions. This joint endeavor bore fruit in 2014 with the introduction of MOVIO (<https://www.gruppometa.it/it/movio>), an open-source kit developed through a partnership between GruppoMeta, the Italian Ministry of Culture (MiC) - Central Institute for the Unique Catalog (ICCU), and the Telecom Italia Foundation, MOVIO aimed to create a versatile toolkit for crafting and disseminating exhibition and tourism guides, digital extensions of real-world exhibitions, and multi-channel virtual exhibitions accessible from various devices such as PCs, tablets, and smartphones. This versatile open-source platform is currently in use at numerous Italian cultural institutions and several European museums and cultural centers.



Figure 4, Examples of MOVIO's websites, source: MOVIO.

MOVIO is also usually paired with another GruppoMeta's open source product, **metaFAD** (<https://www.gruppometa.it/it/metaFAD>), a software for managing the cataloguing process from acquisition to fruition, interacting with linked open data, of archival assets, art collections, and libraries. It ensures compatibility between various standards, allows open data publication, and provides the flexibility of creating dynamic and customizable OPACs. The system is also adaptable and compatible with cloud-based services, including Amazon Web Services, Microsoft Azure, and Google Cloud Platform.

MOVIO's expansion and usage, especially in the national territory, can be attributed to its innovative core functions, which it builds upon:

1. A CMS that organizes multimedia content, supporting common document formats (DOC, PDF, HTML, XML) and various iconographic (image) and audiovisual content;
2. Modules for creating all textual content (ontologies, narratives, news, captions, descriptive cards, presentation pages, etc.) supported by both multilingual backend and frontend interfaces;
3. The flexibility to customize responsive templates and page types in terms of structure and colors;
4. Mobile integration and social interaction to accompany visitors to both physical and virtual exhibitions;
5. Storyteller Module which allows the creation of natural narratives using a media gallery (images, documents, videos, audio), a timeline (placing events or artworks along a temporal axis), interactive geographical maps (locating sites, archives, events, and regional resources

in relational networks), or even slide shows (associating images with various types of content);

6. Addition of sensitive points and highlighted paths to interactive geographical maps;
7. The incorporation of an innovative semantic engine that leverages domain knowledge and explores textual and documentary source, which allows the modeling of exhibition and narrative paths based on logical-thematic hierarchies and conceptual maps.

Despite these features/components, the end result MOVIO manages to produce for institutions and their audiences leads to a simple website, apparently rich in information and content, yet insufficient. Let's examine a practical example from Benedetto Luigi Compagnoni's experience. While he is currently serving as the Archival and Bibliographic Superintendent of Marche, he has held various esteemed positions in Italian national archives and also at the Royal Museums of Turin. His extensive experience includes directing the Archivio di Stato di Milano, a role he fulfilled from 2016 until recently. Throughout his career, he has been actively involved in organizing numerous temporary exhibitions, particularly in Turin and Milan.

Mr. Compagnoni has brought attention to a persistent and significant challenge in preserving the data related to these exhibitions. Often, there were exhibition catalogs available, but not consistently so, which resulted in many exhibitions being nearly forgotten over time except for their titles and dates. In some instances, especially for the most recent events, they utilized MOVIO.

While registering the exhibition, however, not all the content made it online: for instance, the website for the one about the relationship between Napoleon and Milan “Nelle sommosse e nelle guerre. Gli archivi milanesi durante l'età napoleonica” (<https://movio.cultura.gov.it/asmi/nellesommosseenelleguerre/>) one featured only selected exhibits, and documents. Another notable case was the exhibition on Leonardo da Vinci, “Nero su bianco. Carte d'archivio raccontano Leonardo” (<https://movio.cultura.gov.it/asmi/cartedarchivioraccontanoleonardo/>). During this event, a collaboration between a computer scientist and a paleographer resulted in a beautiful digital restoration of one of the documents exposed and the process was displayed during the event. However, this valuable work is not readily accessible today, as the exhibition's website only features the original document and a transcription of the restored version, neglecting to include the process itself.

During the interview, it became apparent that while MOVIO or any other website comprised of still images and text may not be adequate, the true problem exists beyond the tool employed. From his experiences with MOVIO and conserving past exhibitions digitally, Mr. Compagnoni found that there is still a widespread deficiency in expertise and organisation when it comes to approaching these methods. He stated that preservation efforts generally occur after the exhibition has ended, making it harder to collect and preserve crucial data, to “care”. After the exhibition, in fact, there is usually less enthusiasm to put the work to conserve it, as focus moves quickly to the next project.

To tackle this problem, he rightfully suggests, steps should be taken as early as feasible, ideally during or prior to setup. However, he knows how during exhibitions, stakeholders tend to be preoccupied with exhibition-related tasks, which can leave little time or interest in digital preservation activities. Again, the issue with these efforts is more complex than it seems.

2.2 Notable projects

2.2.1. Digital Archive of Temporary Exhibitions and Invisible Museums

Following this overview of the current preservation techniques regarding temporary exhibitions, it is now pertinent to mention two noteworthy projects that have surfaced within the past few years. The first case study, entitled “Digital Archive of Temporary Exhibitions”, explores the creation of a digital archive that captures the multidimensional essence of temporary exhibitions mainly from a design point of view, and the second, “Invisible Museum”, presents on the other hand a more comprehensive platform and methodology for safeguarding their vitality and significance.

Even if they both didn’t have much resonance or further developments, they still remain relevant proposals for approaching the major gaps in this niche field along with the potentialities of these efforts, trying to provide a single product solution to solve them all. Furthermore, they possess the same desire to carry out the task of conserving such intricate cultural events by using the most innovative methods of their times to maintain but most importantly to enhance temporary exhibitions, with this shared vision of navigating and exploiting the reach of the digital transition.

By scrutinizing these two case studies, assessing both their strengths and weaknesses, and acknowledging their distinctive traits and conceivable limitations, I endeavor to attain more awareness of the current state of the art in this field for advancing toward more effective and fresh preservation practices.

Proceeding chronologically, the first project to be discussed is the “Digital Archive of Temporary Exhibitions” by Spagnoli A. et al., developed between 2012 and 2016. This research, despite evident limitations, took into consideration crucial points on the nature of temporary exhibitions and their preservation which had been previously neglected. Indeed, the research stems from the simple yet often overlooked idea that temporary exhibitions are heritage assets of inestimable cultural value, at least for their design aspects, which should be taken into high consideration as an integral part of contemporary design culture.

The authors argued how the rapid setup and dismantling of these cultural events often results in the loss of design traces, with catalogs typically focusing on artworks rather than exhibition design, and consequently, claiming the undeniable potentialities of the digital era in this regard and the need to embrace them. The authors then envisioned a conceptual digital archive that would document, visualize, and enrich the exhibition design process innovatively. For this goal, they identified and underlined the potentiality of hypertextuality in the digital environment, which is able to mirror the multidimensional nature of temporary exhibitions. With respect to the complex design chain of temporary exhibitions, their specific documentation was imagined to be based on the idea of “exhibition as a process” (Nicolin, 2009), or of an “exhibition as a laboratory” (Obrist, 2004).

The Digital Archive of Temporary Exhibitions was thought as a multidimensional experience, a “plural space” for preservation, based on different levels of navigation. For visualizing the design process, a descriptive model using a palimpsest metaphor was introduced, representing horizontal exploration interwoven with vertical layers of technical knowledge. This model organizes information along a timeline, considering both on-stage and backstage aspects of exhibitions. In fact, as generic users can explore vertically or horizontally through links, specialized visitors like scholars, students, and professionals can delve into technical or historical-critical elements. The archive also offers different user paths based on exhibition categories: historical masters, space-reconfiguring exhibitions, and contemporary experiences.

Additionally, this project recognized the variety of personnel involved in the exhibition design process and aimed to act as a mediator between non-experts and specialists across various design disciplines. An interdisciplinary approach was deemed inevitable and to facilitate seamless knowledge exchange, four different configurations were proposed: designer-centric, curator-centric, service-centric, and builder-centric models, emphasizing each actor's contributions and knowledge. The exhibition design knowledge is a system of knowledge negotiated, produced, and shared by all

participating actors throughout the entire exhibition process. This knowledge encompasses process, cognitive, relational, contextual, and temporary dimensions, aiming to provide a comprehensive understanding of the intangible dimension of temporary exhibitions.

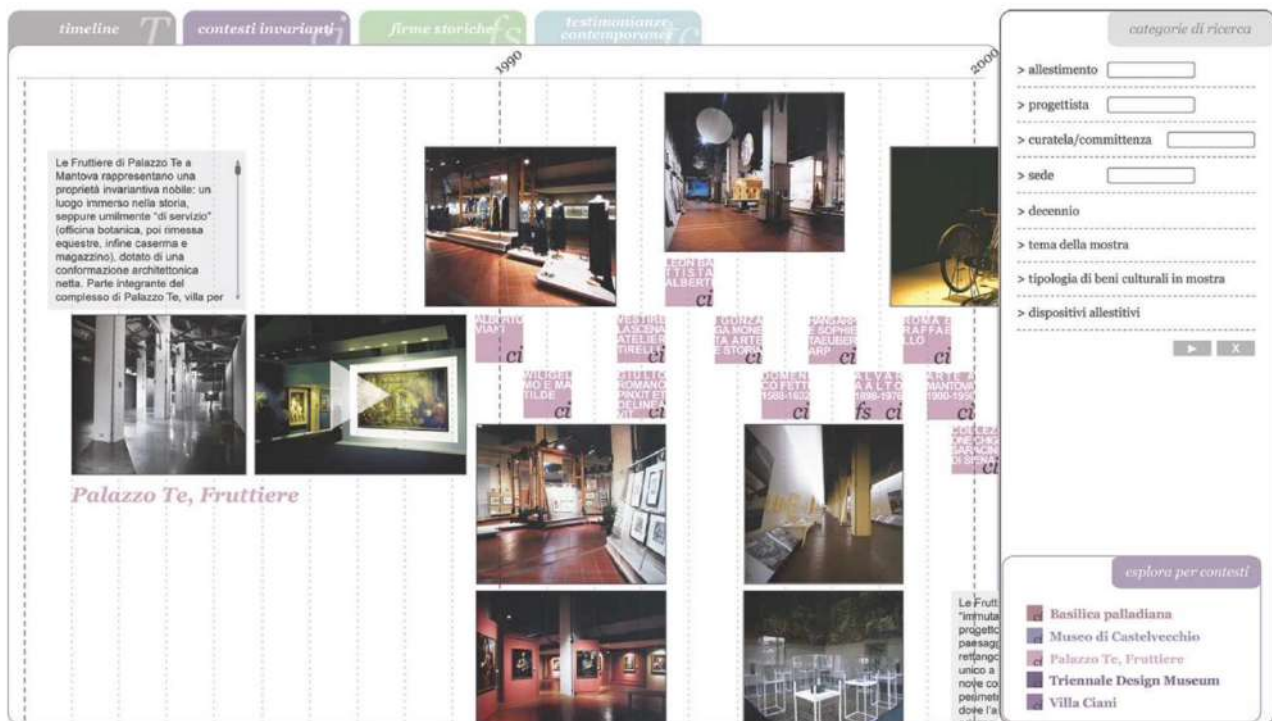


Figure 5, Example of method of fruition to explore the Fruttiere di Palazzo Te in the category Invariant contexts, source: Spagnoli et al. 2016.

Along with the just mentioned potentialities and clever visualization solutions of this endeavor, the project also outlined some relevant difficulties in designing such an archive:

- The identification, finding, selection, and cataloging of various and unusual documents in a systematic manner;
- Imagining a suitable container for this “unusual collection” capable of encoding the hybrid practice of Exhibition Design - a practice that has its nature in a mix of mediums, techniques, and languages and in the relationship with the expositive space;
- The risk of “contradicting” the deep nature of temporary cultural events, designed for an “in presence” fruition.

Moving on to the next example, in 2022, the Institute of Computer Science, Foundation for Research and Technology Hellas (ICS-FORTH) in association with the Computer Science Department of University of Crete put forward a paper titled “A Method and Platform for the Preservation of Temporary Exhibitions”. This work offers a comprehensive approach to address existing limitations in virtual museum implementations and proposes a systematic methodology for

the preservation of temporary exhibitions. To validate the suggested methodology, the authors created a VE to conserve a physical on that took place from 15 May to 27 June 2021 in the Basilica of Saint Mark, making use of sophisticated digitization technologies and an authoring platform named Invisible Museum, created by the same organizations previously.

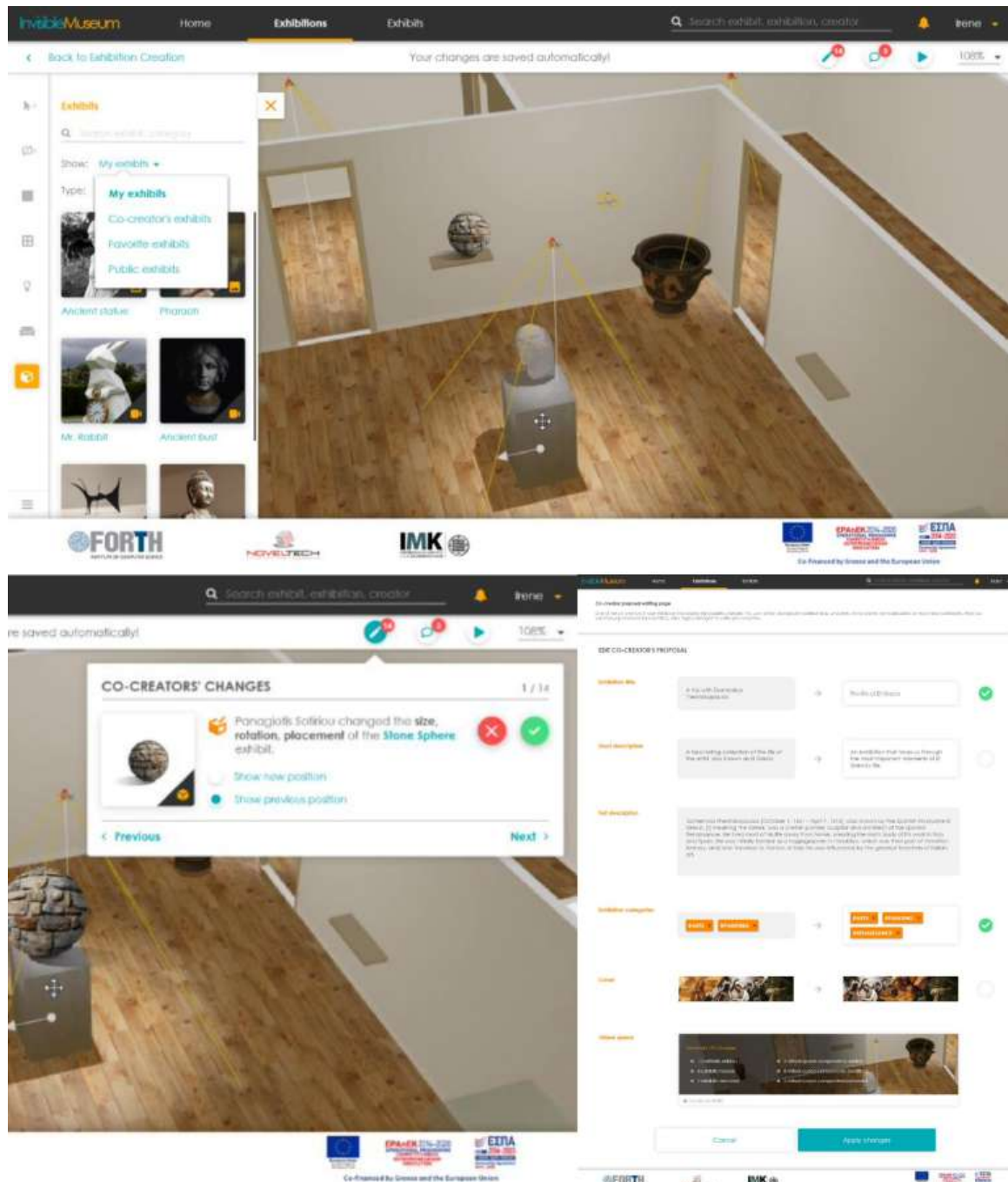


Figure 6, The Invisible Museum's Exhibition Designer tool, source: Zidianakis et al., 2021.

Overall, the study was considered to be successful as the proposed methodology was shown to be sufficient in covering the chosen challenging use case (Pervolarakis et al., 2022). This included various artifacts of different types, dimensions, and forms (such as small dioramas), as well as

digital information presented on site, such as video testimonies and documentaries. However, as of today, the platform is no longer available for the public unless under request, putting the project currently on hold. Then, what caused the delay?

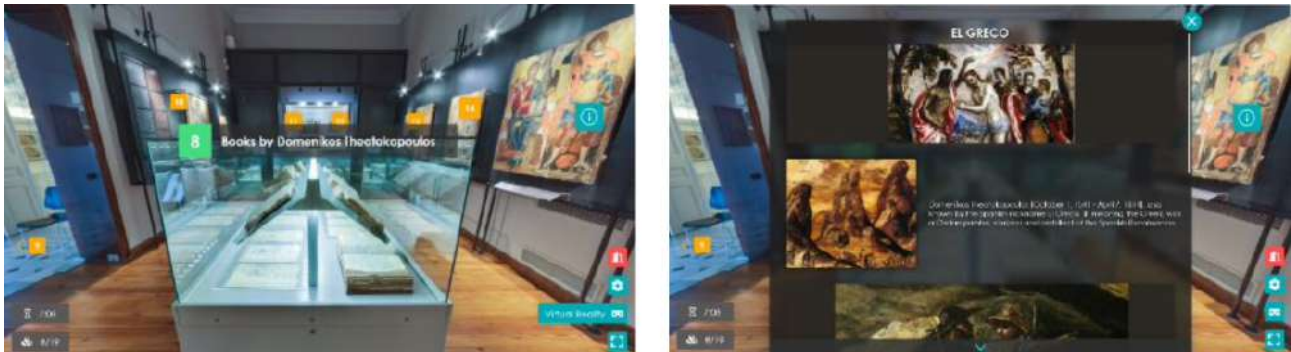


Figure 7, Example of VR Exhibition Tour in Invisible Museum, source: Zidianakis et al., 2021.

During my internship at CNR-ISPC, I interviewed Emmanouil Zidianakis to discuss the initiative. When asked this same question, he stated that the major challenges faced in running the project smoothly were copyright disputes and insufficient funds. To these, it must be added that the study also demonstrates how there is still an important issue to be addressed next: the long-term preservation of the digital assets.

Regarding future work, an issue that should be taken into consideration is the long-term preservation of the digital assets that contribute to the implementation of a VM exhibition. To this end, because the semantic interoperability of knowledge is granted through the CIDOC-CRM, we are planning to store digital assets in open-linked data repositories that are supported by the European Commission, such as Zenodo. (Pervolarakis et al., 2022)

Nevertheless, it is important to acknowledge their noteworthy accomplishments within the context of this research and leverage them to advance further, as the authors' suggested methodology provides the foundation for the framework of this thesis. Furthermore, its implementation resulted in five meaningful findings that must be highly considered going forward.

During the application of this methodology, the authors found that the majority of the time was spent digitalizing the space of the Basilica. However, as the church is typically the venue for the institution's exhibitions, they considered the scanning process worthwhile as it will enable them to reuse the model in future digital exhibitions. More generally speaking, then, it was acknowledged that the digitalization of the exhibitions' environments can be, depending on the space and its

features and the tools adopted in the process, time-consuming but pivotal, especially if that is the area designated for these kinds of cultural events.

The matter is also related to another noteworthy aspect:

The proposed methodology necessitates considerable proficiency, technical resources, and expertise, particularly during the second stage of the process, which involves generating a 3D digital reproduction of the structure. (Pervolarakis et al., 2022)

To address this concern, an online authoring environment was in fact incorporated to enable unskilled users to contribute. These solutions are crucial since exhibitions - whether physical, virtual, or digitally reconstructed - require various and specialized expertise.

Collaboration was also vital as the authors worked directly with the curators to gain a better understanding of the potential of a virtual version of a physical exhibition:

The digital version of the exhibition can be enriched with much more information and content that was not selected to be hosted, mainly due to the lack of space and resources. The digital version can allow curators to work more freely by breaking the space and resource constraints that were applied when designing the physical exhibition. (Pervolarakis et al., 2022)

And lastly, translating the exhibition into the digital realm increases its cultural significance by giving it a permanent dimension, potentially yielding new insights for the CH field as time goes on.

2.2.2. Virtual Technologies

The Digital Archive and Invisible Museum projects were developed to fill a significant void in the Cultural Heritage landscape, serving as centralized solutions. Of the two initiatives, the latter project made the greatest strides in supplying the essential technical elements needed to accurately recreate an entire exhibition for and from various user perspectives. In recent times, there has been a proliferation of platforms and tools customized for art exhibitions that have gained significant prominence within the Virtual Museum sector (Pescarin, 2014). Although these have not been specifically designed for Cultural Heritage preservation, they incorporate core elements needed such as digital libraries, 3D interactive experiences, and extended reality (XR) technologies.

Amid this landscape, the numerous platforms and tools have emerged with distinct sets of features including search capabilities, social media integration, extensibility, content creation, and more. These options also possess various levels of immersiveness and require diverse software and hardware configurations. Prominent examples comprise ArtPlacer (<https://www.artplacer.com/virtual-exhibitions/>), Spatial Metaverse (<https://www.spatial.io/>), the VOV (<https://www.thevov.art/>), CREAM (<https://www.creams-project.eu/>), HoverLay (<https://www.hoverlay.com/>), Remo.co (<https://remo.co/>), and several others. Given their relevance to this dissertation's focus and the unique features, applications, and connections with the subject at hand, I have chosen to analyse three specific projects for analysis: Occupy White Walls, VRallArt, and ATON.

An intriguing embodiment of this concept can be found in Occupy White Walls (OWW: <https://www.oww.io/>), developed and freely available on Steam by StikiPixels. OWW serves as an interactive 3D platform, combining elements of both a social cyberspace and a gaming experience. It caters to users - potentially artists and curators - allowing them to showcase their creations or famous artworks, create their own avatars and virtual environments, invite visitors into these spaces, and engage interactively.

OWW is closely integrated with Kultura (<https://kultura.art/>), a dedicated social media platform centered around art and powered by an AI named Daisy. On Kultura, users can digitally upload their own artworks, complete with relevant metadata, contributing to the formation of a substantial digital library accessible to OWW for exhibition purposes. Upon uploading their items, users are assigned unique codes for each digital object, which can be seamlessly utilized within the digital environment. Daisy also offers art recommendations based on users' previous acquisitions and showcases comments left by other players right inside OWW.

Uniquely tied to its gaming aspect, OWW provides opportunities for leveling up and unlocking various elements, such as materials and furniture, for enhanced customization. Users can open their personal galleries to the community, enabling them to earn income and interact with fellow enthusiasts who will have the ability to leave messages, make art purchases, and offer tips at reception tables.

It is noteworthy that OWW found a certain relevance in the realm of Cultural Heritage when it unilaterally collaborated with the National Gallery (London), a significant initiative that entailed incorporating nearly the entire collection into the game (<https://www.lagalerienationale.com/>). This

comprehensive integration encompassed more than 2,300 masterpieces, including those not currently displayed in the physical gallery and the recreation of some iconic interior and exterior architectural elements of the National Gallery, enriching the virtual environment as well.

Another noteworthy example with a distinct approach is VRallART (<https://docs.vrallart.com/>). The first great point of the platform is that it is specifically design to address different types of users such as artists, galleries, museums, and collectors, allowing them to set up their own virtual exhibitions accordingly to their specific needs. In order to ensure a horizontal understanding of its features, the application provides full and well-rounded documentation to be consulted at any given moment of the setup. Users are also enabled to publish their exhibitions and archive past projects. The digital environments are already pre-defined or one - especially museums can use a cloned physical space. Users can go over searchable lists of artists and artworks and sell their own as monetization model is assessed per project.

Art pieces can also be registered on a secure blockchain, and each piece is clickable with metadata attached to it. While OWW relied on a virtual currency inspired by game industry features, within the ecosystem of ALLART products (<https://all.art/>), VRallART enables users to register artworks on a secure blockchain and consequently even generate NFTs. Additionally, the platform has both a VR and AR client, and can be accessed on a web browser, on a mobile device and on VR googles, which ensures accessibility and flexibility to reach different users' needs.

To offer a diverse regional perspective and yet a similar approach, it is now worth highlighting the ATON framework (Fanini et al., 2021), an open-source tool developed by CNR ISPC, and its various applications. ATON facilitates the creation of Web3D applications for showcasing and enabling online interaction with virtual scenes and objects related to Cultural Heritage. This software leverages contemporary web technologies and standards, ensuring that interactive 3D applications can be readily accessed via a standard web browser, eliminating the need for end-users to install and utilize additional sophisticated software.

ATON is highly adaptable to various devices, including mobiles, multi-touch screens, desktop/kiosk computers, and immersive virtual reality systems. It exhibits scalability from small single-board PCs to large-scale infrastructures. The tool also incorporates advanced features such as camera management, semantic queries, the generation of 3D multimedia annotations, support for collaboration among multiple users, and the facilitation of visual analytics (the study and analysis of interactions in 3D space).

In recent years, numerous Italian projects have aimed to present digital assets, including digitized or modeled materials, through interactive experiences by harnessing ATON. A notable instance is the E-Archeo project (<https://e-archeo.it/en/>), a comprehensive national initiative focusing on eight Italian archaeological sites. E-Archeo has produced multiple online and on-site outputs tailored for both general and specialist audiences (Pietroni et al., 2023). The resulting interactive web3D application (<https://3d.e-archeo.it/a/ales/>), developed using CNR's the ATON framework, empowers users to visualize the digital replicas and virtual reconstructions of the eight archaeological sites spanning from northern to southern Italy. These sites are explored through 360-degree interactive scenarios enriched with multimedia content such as videos, images, and 3D models of individual artifacts. Furthermore, all digital content has been published on Zenodo communities and is available for download (<https://zenodo.org/communities/?p=e-archeo>).

ATON stands as a noteworthy example, emphasizing the significance of the digital transition process and showcasing the value of 3D models in disseminating Cultural Heritage. Further insights into ATON's application will be resumed in the exploration of the Aldrovandi's Case Study in chapter four.

2.2.3. Three Examples of Past Temporary Exhibitions' Digital Reconstruction: Seeing Ireland (Ireland), Stereo Spectacular (Switzerland - France), Palazzo Madama (Italy)

During my internship at Noho, I had the opportunity to interview the team about **Seeing Ireland** (<https://seeingireland.ie/>), a project where they were specifically tasked to replicate digitally a past temporary exhibition starting from a very scarce set of data available. The endeavor is an outstanding/exceptional example that sheds light on the significant challenges associated with reconstructing an exhibition and making it accessible online.

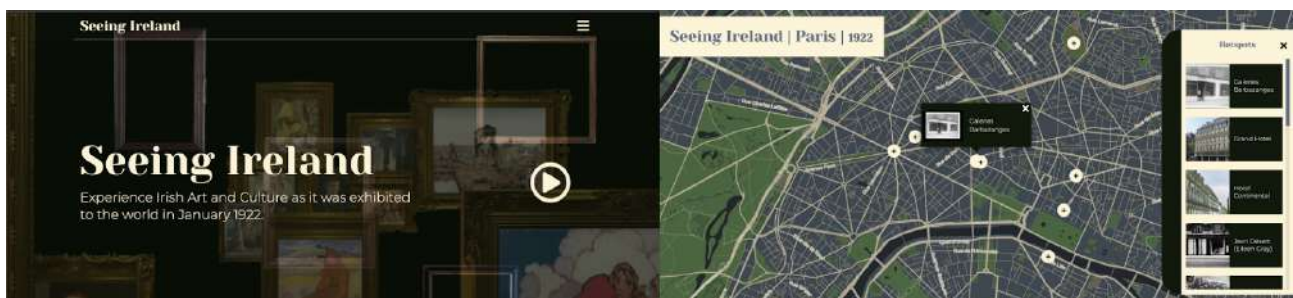


Figure 8, Seeing Ireland's website and interactive map.

Seeing Ireland revisits the Exposition D'Art Irlandais, which took place in Paris in early 1922 at la Galerie Barbazanges. This event played a pivotal role in showcasing the emerging Irish nation and its artistic talents on the world stage: a powerful and historical act of diplomacy and of national postcolonial rebranding. A century later, in 2022, Trinity College collaborated with/decided to partner up with Noho Ltd. to commemorate this event by recreating the exhibition in an interactive 3D environment. The digital gallery features 100 works inputted using an in-house Noho tool called Cross-Culture, which allowed the team to collaborate with the historians involved to enter all the content and produce an additional interactive map related to the event. Exploring the reconstructed room, the user can at any time consult the digitalized original catalogue and access additional materials and resources.



Figure 9, Seeing Ireland virtual environment (on the left) and visualization of the original digitilised catalogue (on the right).



Figure 10, Seeing Ireland's example of object window.

The first challenge in the process was reproducing the exhibition space due to the scarcity of information about the original setup. The design of the space began with/started from a single photograph of a corner in the Galerie Barbazanges, which experts meticulously examined to extrapolate the rest of the room. At this stage, it became evident that achieving historical accuracy, while desirable, was nearly impossible, so a compromise was struck, prioritizing a more user-friendly online design. Then, the most technical obstacle encountered was optimizing the model of the room, consisting of millions of polygons, for online accessibility and fruition.

While technology has made overcoming these challenges feasible, solutions come with a cost in terms of time and budget. Unfortunately, not all cultural institutions, especially non-profit organizations like museums, can readily invest in such efforts. As a result, valuable pieces of information, much like the Exposition D'Art Irlandais, are at risk of being lost forever, as there is no tangible legacy for these exhibitions beyond the little data included in printed catalogs.

Through Noho's team experience, another significant challenge in these efforts became apparent: the need to facilitate seamless collaboration and compromise among stakeholders with diverse skills and objectives within the project. Striking a delicate balance between conveying the experts' intentions and meeting users' expectations is paramount, and companies like Noho navigate this fine line, underscoring the importance of ongoing collaboration.

In the broader context of the discussion on digital preservation, Niall O hOisin, Noho's founder and managing director, acknowledges that it is no longer an ontological dilemma. Temporary cultural events can and should be preserved, much like we purchase live albums or watch recorded concerts, and while they may never fully replicate the physical experience, they play a vital role in preserving their legacy. It is, in fact, essential to move away from an obsession with absolute fidelity to real-life events. Mr. O hOisin highlights how digital environments can, in this regard, help us go beyond, and even enhance real-life experiences, transcending physical constraints and design limitations. As virtual spaces and audiences function differently from their physical counterparts, they offer opportunities for greater material inclusion and information dissemination, ensuring these experiences endure and live on.

Another point made in this discussion with Niall was that, besides budget limitations or a lack of willingness, today, the necessary technological infrastructures are readily available and primed for these undertakings. Just considering the numerous virtual tours and exhibitions held during the COVID-19 pandemic, we as a society have learned invaluable lessons like the feasibility of preserving cultural experiences digitally and the overall the incredible potential of online presence.

In conclusion, as we look to the future, it appears there is still room for exploration around a still unresolved challenge: the embodiment and re-experience of the environments we aim to replicate or interpret. While social and multi-user digital experiences, as seen in video games or initial metaverse experiments, are becoming less unusual or unfamiliar, it's crucial to recognize that not everyone has access to the required technologies or has developed enough interest in their regard.

This underscores the pressing need for broader accessibility and inclusion as we continue on this path.

Another remarkable example of historical reconstruction, driven by collaboration, an interdisciplinary approach, and the invaluable use of archival data and photographs, noteworthy in this state of the art, is Stereo Spectacular. Within the context of the UE1867 Project, a joint effort involving EPFL's Laboratory for Experimental Museology (eM+), MIT Museum, and the University of Paris, a primary objective was to resurrect the Paris Universal Exposition of 1867 using archival stereographic pairs. By skillfully combining cutting-edge technologies with meticulous historical research, the project set out to create an immersive visitor experience, offering a captivating journey into the visual landscape of the 19th-century World's Fair. A demo open to the public was provided in a live online session just this summer, June 16 (<https://swissnex.org/boston/event/the-experimental-museum-ii/>).



Figure 11, Paris Universal Exposition of 1867, Main building at the Champ de Mars, source: Wikipedia.

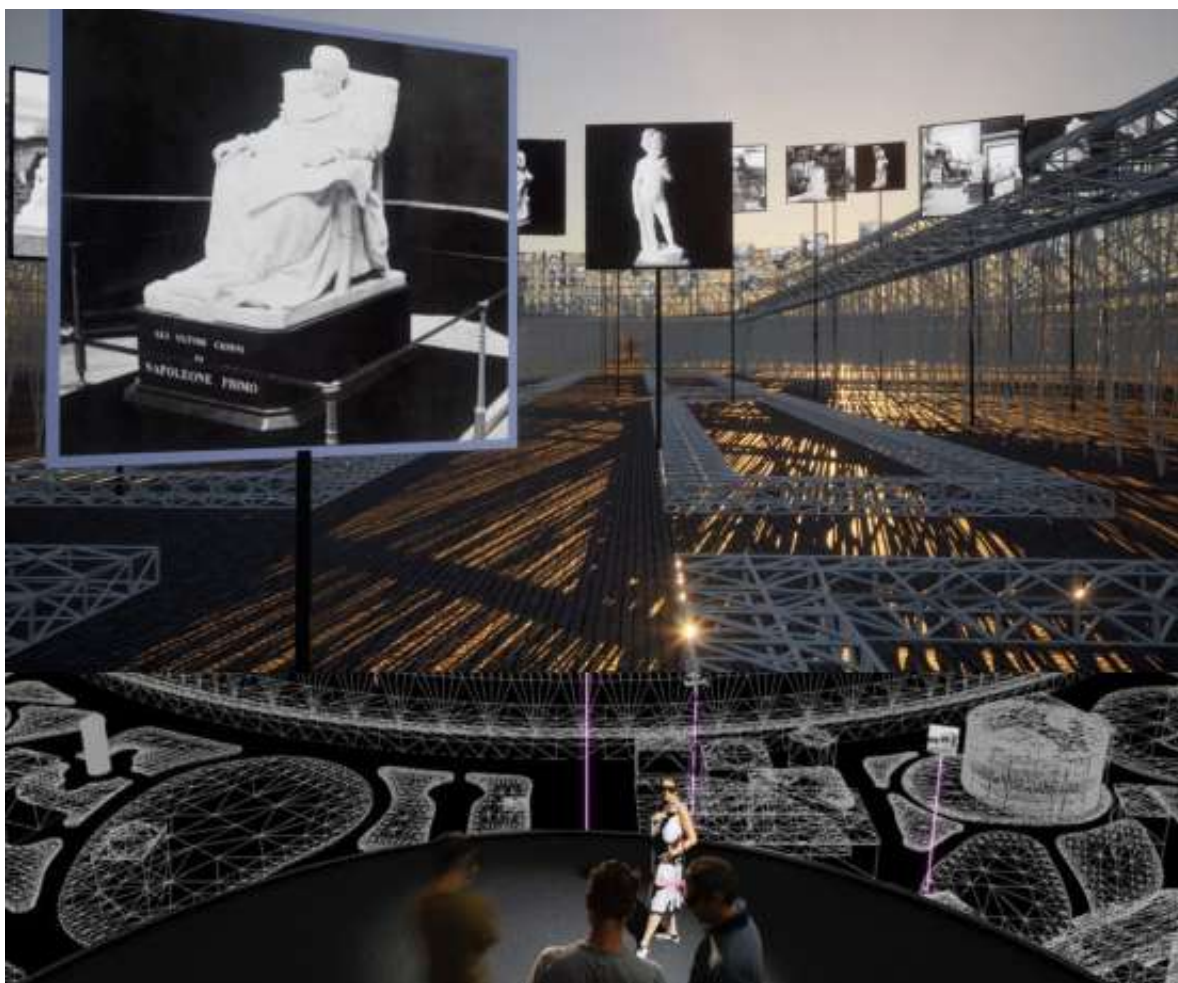


Figure 12, Stereo Spectacular reconstruction (top) and immersive experience (bottom), source: EPFL.

Central to this immersive experience is the Stereo Spectacular installation, a groundbreaking centerpiece that seamlessly integrates various collections. Leveraging computer vision and machine learning techniques, the project breathes new life into the stereographic pairs, transforming static representations into dynamic, embodied, and emotionally evocative spaces. This transformation is facilitated by harnessing the power of game engine technologies, enabling users to navigate and interact within a 3D environment at ultra-high resolutions. Stereo Spectacular reimagines the concept of mapping and offers alternative visual perspectives on historic places and events. Additionally, this project not only revives 19th-century viewing modalities but also provides a contemporary encounter with the multifaceted aspects of modernity that converged at the 1867 Paris World's Fair. Through initiatives like the UE1867 Project and Stereo Spectacular, history is not merely remembered but vividly relived, offering new insights into the past through the lens of modern technology.

Lastly, let us reflect our attention again on the Italian landscape. In the context of an extremely recent international congress titled “I reliquiari a busto tra Italia ed Europa (secoli XII-XVI)”

(<https://www.palazzomadamatorino.it/it/evento/convegno-reliquiari-a-busto/>) held on September 22nd at Palazzo Madama in Turin, guests were provided with VR headsets, enabling them to relive the experience of a temporary exhibition that took place two years prior (<https://www.palazzomadamatorino.it/it/evento/mostra-ritratti-doro-e-dargento/>), in which the aforementioned reliquary busts were displayed. This exhibition had been digitized by LINKS as part of the European project INVENTA 1 (<http://inventa-project.eu>), funded by European Space Agency (ESA) (<https://business.esa.int/projects/inventa>), and is now accessible in VR mode, as well as on desktop computers and smartphones (<https://my.matterport.com/show/?m=1QBgbcFFFFX>).

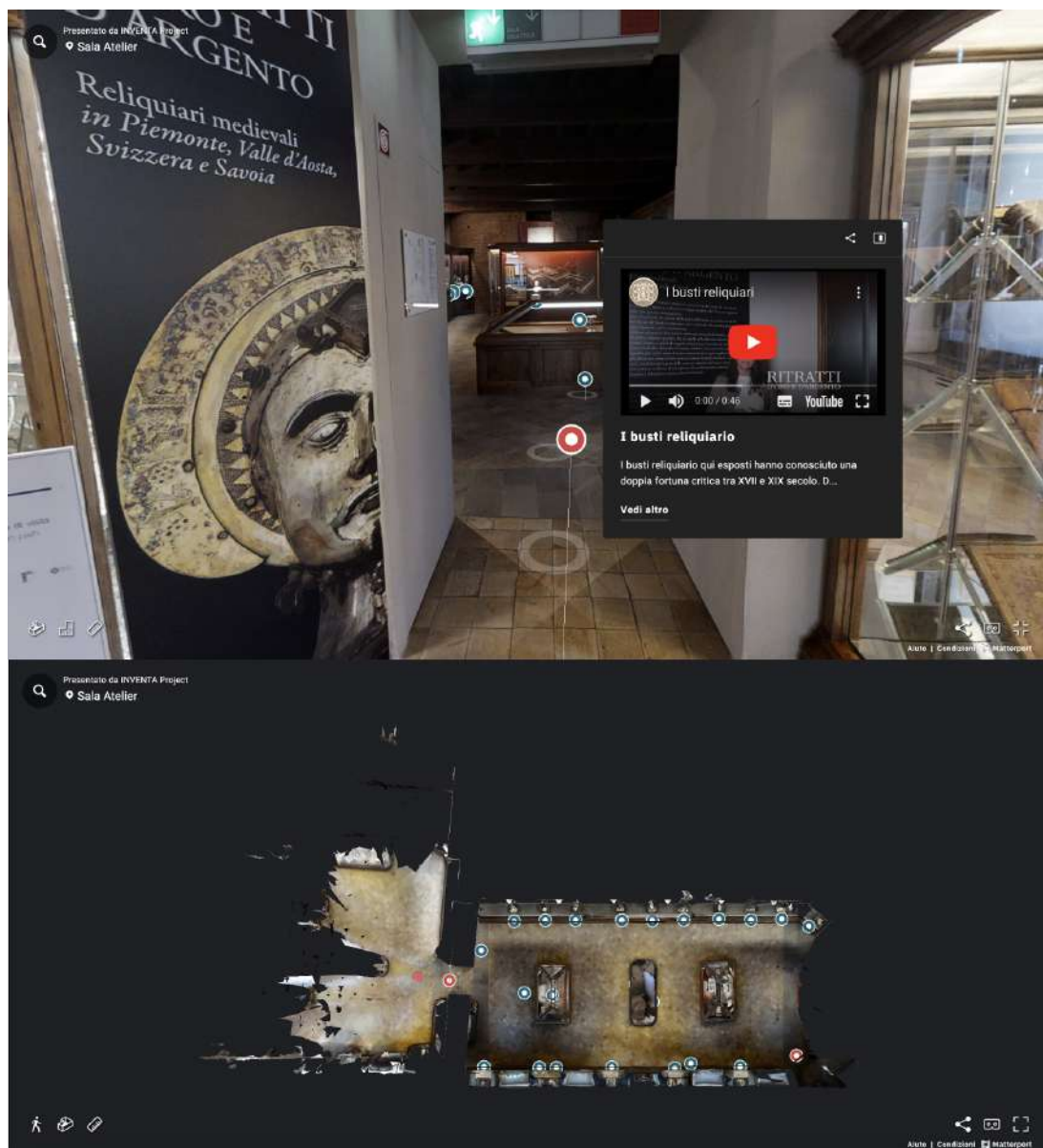


Figure 13, Palazzo Madama's exhibition in Matterport.

The reconstruction of the environment and the exhibited items was achieved through the utilization of Matterport technology. Matterport (<https://matterport.com/>) is a company specializing in 3D

spatial data capture and visualization, which provides not only a platform but also a range of hardware devices and software tools that enable users to create detailed 3D models and virtual tours of physical spaces. This technology has been exploited by various industries, including real estate, architecture, construction, hospitality, and, like in the Palazzo Madama's case, Cultural Heritage. In particular, in Cultural Heritage and museum contexts, Matterport has been utilized to create virtual tours of historical sites, museums, and exhibitions, becoming especially popular and valuable during times when physical access may be limited, such as during the COVID-19 pandemic.

Overall, it offers a powerful and easy-to-use way to capture, document, and share 3D spatial information enabling immersive and interactive experiences for users, with set of valuable customization features. Just looking at the Palazzo Madama's example, some of these may come immediately apparent, such as the visualization of the planimetry and a general sense and overview of the exhibition, hotspots with the main objects of interest, and the possibility to link additional and insightful material otherwise not accessible during the physical experience.

Within the context of this dissertation, though, it is paramount to take into consideration, besides these obvious benefits, also some potential pain points and limitations to its employment. These are all mainly associated with the quality of the digital reconstructions:

1. After the acquisition, there may still be a need for post-processing to fine-tune the reconstruction and address any issues that arise during scanning. It must be also noted that the accuracy and level of detail in Matterport reconstructions highly vary depending on the specific hardware used and the conditions of the scanning environment. In some cases, fine details and textures may not be captured with the desired level of fidelity, which can be a great dealbreaker in the Cultural Heritage field and museums context.
2. Matterport technology is primarily designed for indoor spaces, as it may not perform well in outdoor settings or spaces with challenging lighting conditions.
3. Large spaces too, such as warehouses or open landscapes, may pose similar challenges for Matterport's scanning technology.
4. Matterport is best suited for static environments. In dynamic environments, where objects or people are moving, the scanning process can be disrupted, leading to inaccuracies in the reconstruction.
5. Highly reflective surfaces, such as mirrors or glass, can cause issues with scanning and may result in artifacts in the reconstruction.

Like any other technology involving 3D modeling and the possibility to implement immersive experience, Matterport additionally deals with more common challenges, still open issues in the broader technological field, like:

1. Cost, as the hardware and software required for Matterport scanning can be relatively expensive, which may limit access for smaller businesses or organizations.
2. Compatibility, since viewing Matterport reconstructions may require specific software or hardware, such as VR headsets or web-based viewers, which are still relatively common.
3. Maintenance, as Matterport's software and hardware may require updates and ongoing maintenance to ensure optimal performance and compatibility with evolving platforms.

2.3 Conclusions

Chapter 2 has delved into the innovative approaches and technologies employed to safeguard and make accessible temporary exhibitions' rich legacy. Divided into two main sections, it has first offered in Section 2.1. an extensive examination of the challenges associated with preserving temporary exhibitions, exploring the preservation techniques and technologies historically employed up until now (2.1). These challenges span from the inherent ephemerality of such events to the intricate task of capturing their multifaceted nature.

In Section 2.2, the “Digital Archive of Temporary Exhibitions” and the “Invisible Museum” projects recognized the significant cultural value of temporary exhibitions, especially their intricate design aspects, and proposed innovative and comprehensive digital solutions to document and preserve these events for future generations. However, they also shed light on the obstacles related to funds allocation, legal disputes, document identification, design representation, and the harmonization of digital preservation with the in-person character of temporary exhibitions' experiences.

The subsequent exploration in Section 2.2.2 explored the capabilities of existing platforms and tools, showcasing three key projects, “Occupy White Walls”, “VRallArt”, and “ATON”. These projects demonstrated the transformative power of innovative features such as Web3D applications and blockchain integration. Within this analysis, the importance of collaboration and accessibility emerged as vital themes, underscoring the need for diverse user access and ongoing cooperation.

Section 2.2.3 was dedicated to projects specifically tailored to digitally translating past temporary exhibitions, including “Seeing Ireland”, “Stereo Spectacular”, and the utilization of Matterport technology at Palazzo Madama. These initiatives illuminated the challenges of digital reconstruction and online accessibility, while also demonstrating the potential of 3D representations and virtual environments, thus enhancing and expanding thanks to them the original exhibitions’ appreciation.

Collectively, these sections underscore the possibilities of digital technologies in preserving and revitalizing temporary exhibitions and offer valuable insights into the ever-evolving landscape of cultural heritage preservation. The key takeaways revolve around the significance of interdisciplinary collaboration, accessibility, and user engagement in preservation efforts. Additionally, it is recognized that digital translation has created a new and different space and audience, each with their distinct regulations and necessities (2.1.1. and 2.1.2.). While the digital sphere holds tremendous potential for surpassing physical preservation limitations and providing access to cultural heritage experiences, it also necessitates constant exploration and adaptation.

3 FRAMEWORK

As highlighted in the preceding chapters, in an age characterized by rapid digital transformation and expansion of the Cultural Heritage sector, preserving and presenting temporary exhibitions has become a complex and multifaceted challenge. This third chapter builds upon the literature review previously presented, discussing the development of a framework that synthesizes the significant findings and lessons learned, and forming the foundation for subsequent discussions. In developing this methodology for the digital preservation of temporary exhibitions, a primary key objective was to evaluate the crucial constituents, specifically by exploring potential challenges and suggesting viable solutions. This approach aims to identify areas that demand focused and immediate attention and potential remedies. Additionally, this investigation briefly delves into anticipated future development and scenarios, contemplating the Metaverse's possible deployment and impact.

Within the context of this dissertation, the term “framework” refers to a structured and adaptable overview that offers a systematic means of addressing the various challenges associated when digitally preserving temporary exhibitions. Unlike one-size-fits-all solutions, like those proposed by the Digital Archive of Temporary Exhibitions or the Invisible Museum, this approach offers rather an abstract methodology that institutions can tailor to their unique objectives, resources, and capabilities.

3.1 Framework Boundaries and First Assessments

Before delving into the intricate details of this framework, it is essential to first ponder the wide variety of institutions responsible for this stewardship. This understanding will lay the groundwork for identifying common key elements essential for the outline of the methodology, and for aligning each institution and each exhibition with the most suitable preservation strategy.

The institutions responsible for hosting temporary exhibitions are equally diverse and complex as these initiatives, reflecting a broad spectrum of internal structures and missions. They include museums, galleries, cultural centers, universities, parks, and more, each bearing unique responsibilities and heterogeneous objectives spanning from education and research to public engagement and cultural preservation, with varying degrees of commercial interests (ICOM, 2010). Within this intricate landscape, as also illuminated by the various projects analyzed in the second chapter and based on the insights of experts intimately involved in these initiatives, several

recurring constraints challenge the execution of digital preservation endeavors. These factors, interlinked and reinforcing each other, often trigger a chain reaction, forming barriers and impeding institutions from being well-equipped in terms of strategy and resource allocation, ultimately affecting their ability to carry out effective digital preservation endeavors.

While the advantages of digital preservation - such as increased accessibility, broader dissemination, and enhanced engagement - are today undeniable, some institutions may still exhibit reluctance or lack enthusiasm for these types of efforts. Their hesitance often arises from concerns about losing the physical engagement that traditional methods offer (which had however proven to be limited and insufficient for this complex task) or from a deeply ingrained conservative attitude regarding Cultural Heritage matters. In many cases, institutions may also hesitate as they perceive the transition to the digital domain as a daunting or unnecessary task, potentially viewing it as an additional burden rather than a valuable opportunity. This attitude ultimately deterred them from prioritizing these digital solutions.

Furthermore, it was clear that budgetary restrictions seemed to occur in the majority of cases, in addition to the aforementioned “attitudinal issue”. Many establishments, especially smaller ones, function with limited finances and often experience difficulties in allocating funds to sustain these endeavors. These budgetary restrictions, therefore, have a cascading effect as they evidently compel institutions to prioritize other activities while neglecting preservation.

The first consequence of this chain reaction will then be the lack of data preservation, as, without adequate investment, institutions may not preserve essential data, making it challenging to reconstruct past exhibitions or initiate preservation efforts after an exhibition's conclusion. This has been shown, for example, in the case of Seeing Ireland or Luigi Compagnoni's experience. Additionally, while some institutions may already be equipped with in-house experts capable of leading such undertakings, others may lack specialized knowledge and expertise in this domain, especially when approaching digital solutions. Similarly, budgetary constraints can also lead to a lack of technological readiness as some institutions may lack the necessary hardware, software, or technical expertise required for digital preservation projects.

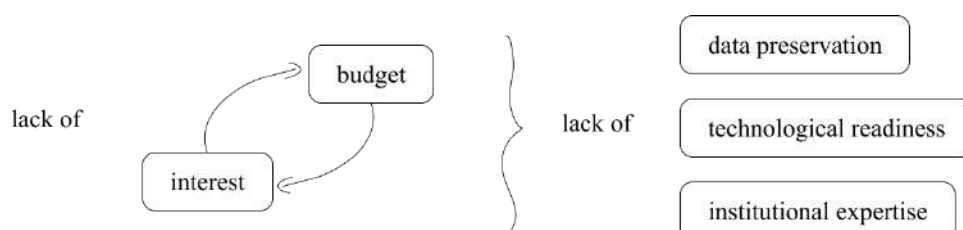


Figure 14, Visualization of the primary barriers and their relations.

Among these various constraints, one of the most challenging yet essential to address is the aspect of interest or attitude of institutions in the cultural heritage field. Then, how to navigate and overcome this pain point? This reluctance does not diminish the importance of digital preservation efforts; instead, it underscores the need for increased awareness, education, and advocacy within the Cultural Heritage sector.

Highlighting the positive implications of digital preservation, such as examples of success stories and its tangible advantages, may motivate institutions to adopt this essential practice and facilitate the exchange of best practices and data, demonstrating the collective value of these preservation efforts. However, despite potential institutions' willingness and good intentions to approach digital preservation efforts, objectively, limited budgets and resources may lead to the same hesitance in undertaking digitization solutions. This reluctance can be attributed to the widely held belief that these initiatives are an added burden, rather than an opportunity, making them appear as merely daunting and unnecessary.

The framework presented here, indeed, moves in this exact direction as it aims to break down this belief and provide clarity and guidance in adopting specific strategies while also helping institutions anticipate and overcome potential challenges in the preservation process.

It is, therefore, crucial to discuss a fundamental distinction before moving forward—one that delineates the basic from the sophisticated: the differentiation between a Minimum Digital Preservation and the full Digital Twin. This demarcation will serve as a guiding principle, helping institutions navigate the complex terrain of digital preservation in a manner that is both pragmatic and aspirational. Moreover, it serves to clarify that these endeavors do not necessitate an “all or nothing” approach but can be tailored to an institution's specific needs, resources, and ambitions.

First and foremost, the minimum threshold of exhibition digital preservation, still barely met in the current landscape, needs to be ensured. This basic level guarantees an essential and bidimensional, yet invaluable, documentation of these cultural events, akin to cataloging their physical counterparts. However, this would represent the mere foundation—the “skeleton” upon which richer, more advanced preservation could be potentially built. By embracing this approach as a practical starting point, institutions can dispel concerns related to extensive budgets, staffing, or complex technologies, as it doesn't be a daunting endeavor. In fact, institutions can leverage existing resources, such as their websites, to transform them into more robust and comprehensively documented exhibition archives. The implementation may vary from institution to institution, with

some choosing to enhance their institutional websites by dedicating a section to past exhibitions, while others may employ separate resources or specific platforms for this purpose.

Conversely, cultural institutions with greater resources and capabilities can choose to go beyond this level. These institutions may have already digitized their entire collections or even developed immersive virtual tours. By pursuing more extensive preservation efforts, they can aim for an ultimate goal: achieving a complete Digital Twin of their exhibitions. The full Digital Twin represents a sort of aspirational pinnacle of this preservation process, and while it demands a higher level of investment and resources, it walks closer to replicating or at last restoring the entirety of the in-real-life event.

In discussing Digital Twins in this context, it is important to make a brief semantic and conceptual note, as there exists an ongoing debate around their definition. Various efforts have emerged to categorize and define them systematically, suggesting conceptual dimensions and characteristics (van der Valk et al., 2020; Qi et al., 2021). These definitions commonly share attributes like virtual-physical pairing, data connections, and simulation capabilities, along with key elements such as physical and virtual entities, environments, metrics, and more (Jones et al., 2020). Recognizing, however, that Digital Twins can take different forms across various contexts and applications, some argue that these requirements might be overly restrictive and propose a more generalized approach focused on essential elements, avoiding context-specific terminology (VanDerHorn & Mahadevan, 2021).

In particular, in the realm of Cultural Heritage, implementing a Digital Twin poses substantial challenges as many of the standard requirements may not align with the unique characteristics of this field. These include intangible elements, dynamic temporal changes, intricate influences, or even the physical object's non-existence –much like in the case of temporary exhibitions (Gabellone, 2022). Nevertheless, there is potential for reimagining Digital Twins in the Cultural Heritage domain, utilizing frameworks like HBIM. Niccolucci et al. (2023) argue that features like continuous data exchange and bidirectionality, while feasible, shouldn't be rigid prerequisites due to the often intangible or transient nature of heritage. This approach enables dynamic evolution, resulting in a precise and versatile “knowledge model” resembling a Digital Model. Over time, this model can potentially evolve into a full-fledged Digital Twin, tailored to the distinctive requirements and complexities of Cultural Heritage preservation and exploration.

In the context of exhibitions, Digital Twins means creating virtual counterparts of physical in-real-life exhibitions, replicating not only their appearances but also their properties, behaviors, and experiences, building the foundation to go beyond. This transformation transcends the mere documentation of exhibits and design; it mimics the exhibition's essence and offers visitors and experts the opportunity to experience it again, in a new format, even after its physical closure. The journey to this result could be seen as a sort of modern odyssey that involves sophisticated technologies, data integration, semantic richness, and an unwavering commitment, but that also allows for interactivity, exploration, and a deeper understanding of the historical, cultural, ultimately human significance of an exhibition.

Lastly, I want to underline that the distinction just discussed between minimum digital preservation and the concept of a Digital Twin stems from two pivotal lessons learned in the extensive literature review, with a significant focus on the OSCI framework's outcomes. In this multifaceted challenge, considering the vast array of variables at play, it becomes not just a wise choice but a necessity to commence these digital preservation efforts with an initial assessment of the stewarding institution's unique characteristics and available resources, particularly its technological infrastructure. This foundational understanding underpins the entire approach to the preservation and presentation of exhibitions.

Having explored the institutions responsible for hosting, curating, and safeguarding exhibitions, and distinguished between the Minimum Requirements for preservation and the more ambitious concept of the Digital Twin, it is crucial now to better explore the essence of exhibitions themselves and define their core components, the ones to be preserved.

Let us consider a definition of the exhibition borrowed from outside and not drafted by ourselves. This term –along with its abbreviated term ‘exhibit’ – means the act of displaying things to the public, the objects displayed (the exhibits), and the area where this display takes place. (Davallon, 1986).

As previously explored, an exhibition is “not an illustration” (Obrist, 2014), not a mere display of selected items, and it is from this idea that in the “Key Concepts of Museology”, ICOM, the International Committee for Museology, derived their official definition:

The exhibition, understood as the container or the place where the contents are on display (just as the museum appears both as a function and as a building) is characterized not by the architecture of this space but by the place itself.

From this viewpoint, they then moved forward, adding that this space is not only determined by its physical structure and the items it contains, instead, it is also shaped by the individuals, including visitors and museum professionals, who enter and interact with this space. This perspective transforms the exhibition venue into a unique hub for social interaction, which has led through the years to the development of visitor studies and a specialized research field focused on the communicative aspects and unique interactions within the exhibition space, as well as the imagery and ideas it may evoke. Exhibitions, therefore, go beyond the mere display of physical artifacts, encompassing content, context, and the physicality that collectively shape the visitor experience, both within and outside the exhibition's walls.

This specialized communication system, as proposed by scholars like McLuhan and Parker (1969) and Cameron (1968), takes into consideration also the wider range of elements actually considered “exhibits”, including *musealia*, genuine museum objects, substitutes like casts, copies, photographs, as well as display materials such as showcases, partitions, screens, and information tools like texts, films, or multimedia. Within an exhibition, these exhibits serve as signs within the realm of semiotics, and the exhibition itself is seen as a communication process, often one-way, incomplete, and open to diverse interpretations. This understanding of exhibitions distinguishes them from mere presentations. While the latter can refer to a physical and didactic discourse or a complex arrangement of displayed items, exhibitions involve a dynamic process of expressing exhibits.

These modes of expression have evolved over time, influenced by varying tastes, styles, and the roles of individuals involved in creating the exhibition space, such as decorators, exhibition designers, display designers, and stage designers. In this regard, the existing literature has tried to categorize them in a sort of hierarchy (Barry Lord & Gail Dexter Lord, 2002) or through the deployment of the more flexible and broad advocacies’ concepts:

Naturally, depending on the size of the project, the budget, and the setting, there might be any number of people involved in the development, design, and fabrication of an exhibition, but we propose that there are only five main areas or *advocacies* that need to be represented on any and all teams:

1. Advocacy for the Institution
2. Advocacy for the Subject Matter
3. Advocacy for the Visitor Experience
4. Advocacy for the Design (physical and sensory)
5. Advocacy for the Project and Team

Ordinarily, each of these is embodied in a single person on a team, but in smaller institutions, an individual may need to take on more than one role, and in larger institutions with larger projects, there may be a multitude of people working from the point of view of a specific advocacy. (Polly McKenna-Cress & Janet A. Kamien, 2013).

Furthermore, the nature of exhibitions varies according to different disciplines and the objectives of the exhibition, encompassing diverse media like objects, texts, moving images, environments, digital technology, and mono-media or multimedia presentations. Exhibitions can also differ in terms of profit orientation, as before ahead suggested, ranging from research exhibitions to blockbuster shows and commercial exhibitions. Notably, visitors have become increasingly engaged in this wide spectrum of possibilities related to exhibitions through the deployment of new means of interaction, which include also modern technologies like, for example, immersive experiences. Despite this diversity, the multifaceted realm of exhibitions stays consistent in its core elements, which can be synthesized as shown in Fig. 15.

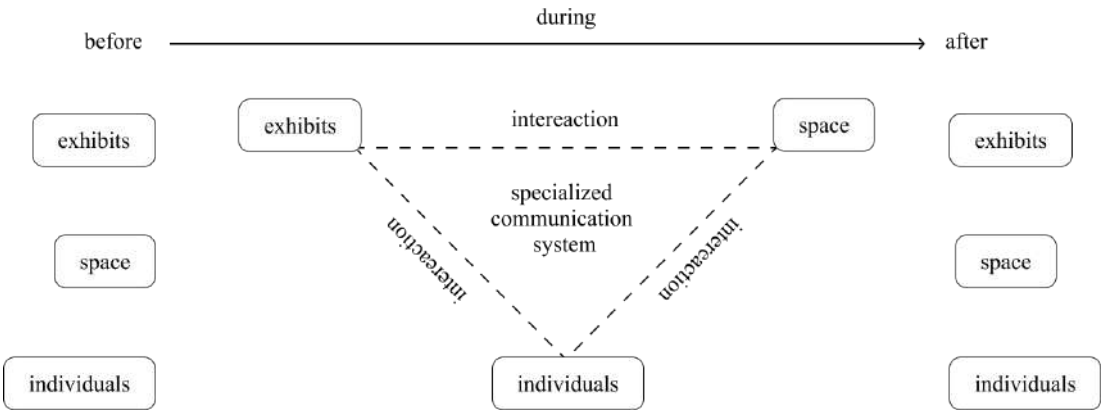


Figure 15, Visual representation of an exhibition timeline, core elements, and their interactions.

It must be noted however that the ICOM's definition of exhibitions, while undeniably relevant and comprehensive in taking into consideration the main elements involved, still misses out on the assessment of one aspect, perhaps not always thoroughly illuminated, which I found in my exploration to be, on the other hand, quite crucial. And that is the dimension of time – the “when” of exhibitions.

Exhibitions are not static entities, as said; rather, they are dynamic expressions that unfold over time. Every phase of an exhibition's journey, from inception to deinstallation, contributes to its identity, its impact, and its role in our cultural landscape. The process of conceiving, planning, curating, and designing an exhibition is marked by distinct temporal markers, each laden with

significance, and changes. Moreover, exhibitions often carry the hallmark of transience, existing within finite temporal boundaries, and presenting unique challenges and opportunities. Exhibitions are typically temporary, existing for a specific duration: this inherited ephemerality is part of what defines them, as they are meant to provide a unique and time-bound experience to visitors. The notion of time, therefore, plays indeed a significant role in how exhibitions are conceived, organized, and experienced. And also remembered and preserved.

While the argument for time as a fundamental component of exhibitions may be subject to debate, there's no disputing its undeniable importance in the context of preservation strategy. As discussed earlier, in fact, one of the primary challenges facing preservation efforts is the deficiency in data collection, or better of a comprehensive data collection regarding what occurs before, during, and after an exhibition: the deficiency of a good strategy of preservation throughout and about the whole lifecycle. This understanding has emerged repeatedly during my analysis of existing literature around it, compared to the insights gleaned from the responses to my first questionnaire and the one-on-one interviews full of real-life examples. Now, let us delve into the key findings. Even the most comprehensive descriptions in literature often leave gaps and overlook critical elements in the exhibition lifecycle, as they may stop at the installation phase or simply acknowledge potential further revisions (Barry Lord & Gail Dexter Lord, 2002; Polly McKenna-Cress & Janet A. Kamien, 2013).

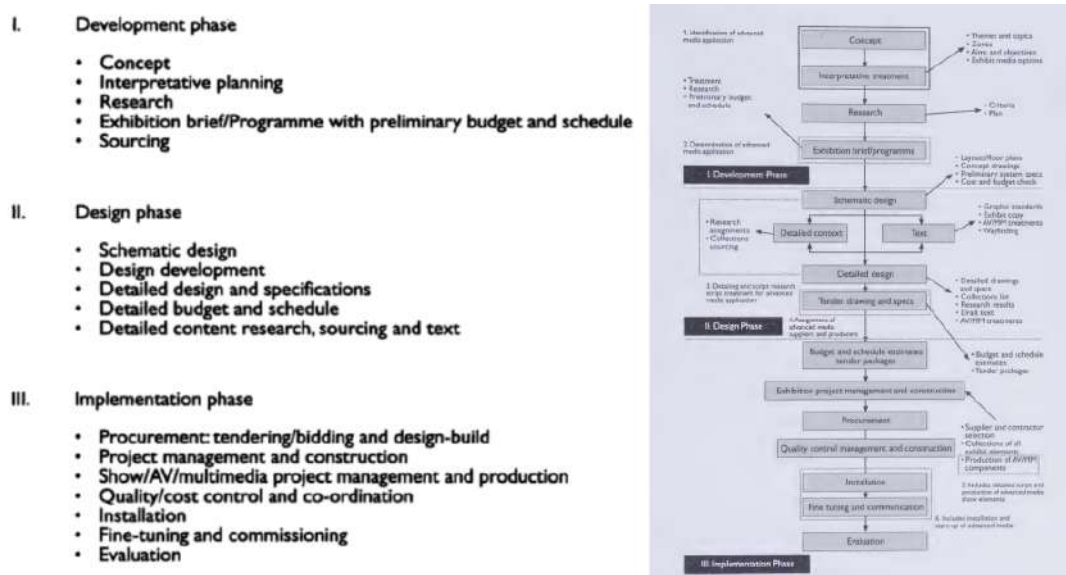


Figure 16, Exhibition pipeline by Barry Lord & Gail Dexter Lord, 2002.

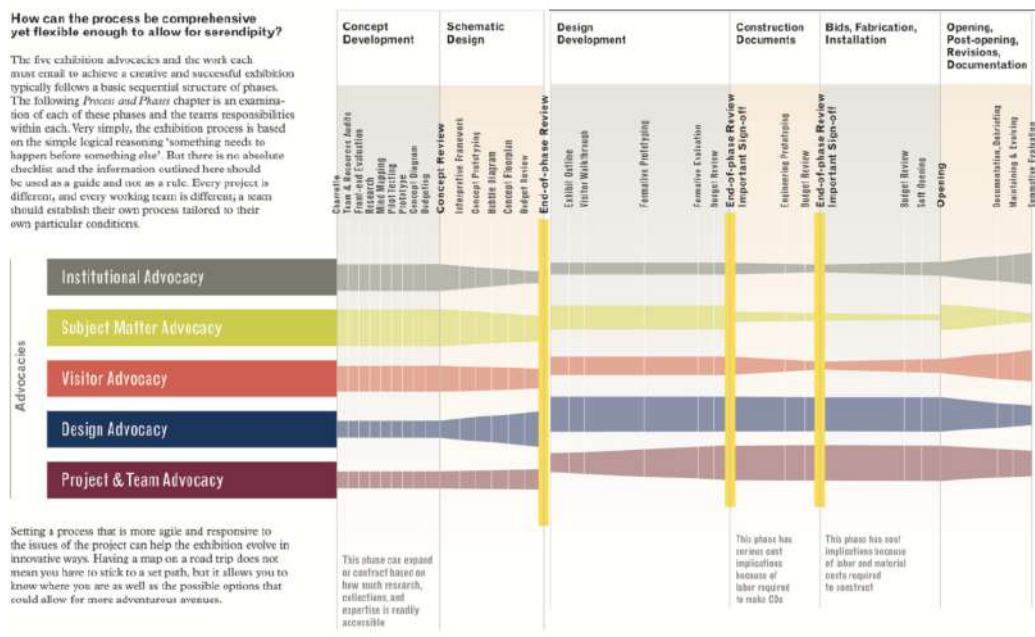


Figure 17, Exhibition pipeline by Polly McKenna-Cress & Janet A. Kamien, 2013

Often, then, the focus is predominantly put on the exhibition's creation, curation, and presentation, with insufficient attention paid to preserving the processes and materials involved; a big light shed on the “before”, one softer one on the “during”, utter darkness around the “after”. This tendency was registered in the questionnaire as well: only two of the participants, when asked about the exhibition’s process, mentioned activities after the initial installation and opening. These included user testing, monitoring, and updates, which shouldn’t be overlooked; on the contrary, it is exactly after the initial installation and opening, that there is a more significant need for continuous attention and documentation activities. Exhibitions should be viewed as dynamic entities that evolve to meet changing needs and audience expectations: they are not static showcases, but living, breathing experiences that adapt over time. This dynamic nature is especially evident in virtual exhibitions, where digital interactions and user feedback play a pivotal role.

More pragmatically, changes of plan simply happen. The majority of answers registered in my questionnaire state that they may occur “sometimes” or “often”. Compromises between parties involved, unforeseen casualties, users’ responses, original proposals may be altered or even discharged or just never come to life as seen as unnecessary, specific exhibits substituted due to emergencies; the list of possibilities goes on and on. Changes can manifest in various ways, and while they are a part of the process as significant as any other, they might not be as well-recorded, leading to gaps in documentation and information, making it challenging to retrace the exhibition's journey accurately in the future.

However, it is the “after”, the post-exhibition phase, that presents some of the most pressing preservation challenges. Once an exhibition concludes, attention naturally shifts to new projects and initiatives, potentially resulting in the inadvertent neglect of critical preservation efforts, as frequently happened, for example, in the past in Mr. Compagnoni’s long experience in this field. The insights, documentation, and materials generated during the exhibition's lifecycle can be at risk of fading into obscurity, a loss that can hinder future scholarship and appreciation of the exhibited content, if not well-documented.

Furthermore, exhibitions continue to exist in both the physical and digital realms even after their official end, primarily through individuals. Modern-day attendees frequently share their exhibition experiences online by sharing photos, videos, and reflections. These "reflections" could come from “specialised visitors”, including scholars or curators, who may provide critical reviews or initiate further studies based on the exhibition's highlights. It is then crucial to acknowledge the significance of these “aftermaths” as they provide valuable insights into the way in which an exhibition was perceived, its impact on the audience, and the lasting dialogues it may have initiated. For galleries and institutions, such as the Solomon Art Gallery previously mentioned, documenting and preserving records of post-exhibition interactions is essential in comprehending the lasting influence of exhibitions. Ideally, these elements could be integrated into the final preservation outcome through several means, such as creating links to online sources of these activities or exploring more advanced solutions.

Additionally, it's essential to note that the post-exhibition phase is also an opportune moment for preservation efforts to be released publically and alleviate concerns that making content available online might discourage physical visits. On the contrary, when digital access complements the physical exhibition, it can enhance the overall experience and broaden its reach beyond its conclusion. This dynamic interplay between physical and digital access highlights the iterative nature of the exhibition process as shown by the questionnaire’s answers, where adjustments and improvements happening throughout the whole lifecycle symbolize the ongoing interaction between individuals and space and exhibits.

Lastly, the importance of collaboration cannot be, at this point, overstated. My questionnaire responses too highlighted how collaborations are integral throughout the whole exhibition lifecycle, as professionals from different backgrounds and with different skills work together to make these extensive efforts happen. Each contributor brings their unique insights to create a cohesive and engaging experience for visitors. Additionally, the interviewees revealed that nowadays these

collaborations often take place through the deployment of cloud-native platforms and tools Figma, Google Drive (3), One Drive Microsoft, Drive (not specified if Google or Microsoft), Workplace, Spatial, Learnbrite, VVVV, Aton, GitHub, Trello, Slack, Basecamp, Miro (2), Dropbox, Adobe CC, Teams, WeTransfer. These tools facilitate seamless communication, file sharing, and project management among team members, ensuring that everyone is on the same page.

3.2 Second Assessments and Pipeline

Thus far, this inquiry has navigated the boundaries of our preservation framework:

1. Defining the institutions leading this stewardship;
2. Exploring and completing the core elements of an exhibition, the ones to be preserved;
3. Underscoring the role of temporality in the exhibition lifecycle, and scrutinizing the continuum of preservation efforts;
4. Making a distinction between the minimum requirements to the ambitious concept of a “digital twin”.

At this point, in order to ensure the groundwork for both the extremities of our digital preservation goals (Point n. 4), it is opportune to conduct a second assessment regarding the realms in which the exhibitions occur, and by extension, the nature of the data assets they encompass. This involves a categorization into three distinct paradigms - traditional, hybrid, and digital; each typology with its own attributes and preservation exigencies.

The need for this second assessment arises from a dual imperative. Firstly, it acknowledges the ever-evolving and multifaceted landscape of exhibitions, driven by the relentless advancements in technology and its myriad applications in this field. Secondly, it empowers institutions with the ability to craft preservation strategies that are not only comprehensive but also adaptive and responsive to the distinctive demands of their exhibitions. This classification aims, therefore, to lay a solid foundation for the core digital assets’ creation. It serves as a roadmap to navigate the diverse exhibition terrain effectively, inching closer to the aspired “zenith” – the realization of an all-encompassing, immersive digital rendition of an exhibition, referred to as the “digital twin”.

With the three primary scenarios established, encapsulating the possible realms of exhibitions and delineating their distinct assets, the subsequent phases of this inquiry will involve a comprehensive exploration of the different levels of digital assets' creation. These levels will be described in detail,

with a specific focus on the core elements that constitute an exhibition: exhibits, space, individuals, curatorial elements, and their interconnections. This analysis will be included in the exploration of the remaining phases of the digital preservation process, coming after the initial assessments already discussed. At each required step, the variations from one preservation level to another will be highlighted.

Lastly, a meticulous examination of the potential challenges and complexities inherent to each realm, across varying levels of digital preservation and steps of the pipeline, will be discussed. From the fundamental minimum requirements to the visionary pursuit of a “digital twin”, I will scrutinize the obstacles and open issues that institutions may encounter.

Traditional Physical Exhibitions:

- Traditional exhibitions primarily feature tangible, physical artifacts, ranging from paintings, sculptures, and historical artifacts to multimedia installations;
- These exhibitions are confined by physical space, relying on supplemental text and the background knowledge of visitors to provide context;
- Visitors engage with these exhibits through observation, reading accompanying descriptions, and appreciating the artistic or historical significance of the displayed items.

Overview of Digital Assets Creation and Potential Challenges:

Traditional exhibitions, deeply rooted in physical artifacts and experience and temporary in nature, present a profound challenge when it comes to their digital preservation. The task at hand goes beyond the practicalities of resource allocation; it involves a fundamental transformation of something inherently physical into a digital format. The complexity level of digital preservation is at its highest.

The primary hurdle is undoubtedly the extensive digitization effort required, as (nearly) all components, from artworks to exhibit designs, must be meticulously transformed into digital assets, demanding a significant commitment of resources. However, the challenges do not end with the practical. They extend into the conceptual and interpretational domains. Preserving the essence of a traditional exhibition necessitates capturing not only its primary components, but also understanding and replicating the intricate interconnections among these elements. It requires the translation of that “specialized communication system” which is the whole exhibition's process and experience into a new context—the digital environment—while preserving its original intent, concepts, and context.

One of the most profound challenges lies, therefore, in the reinterpretation of this intricate web of connections for its new realm and audience—the digital. As they exist in different ontological dimensions, the goal should not be to simply mirror or overlap them. Instead, it is to foster a meaningful dialogue between the physical and the digital, making the latter an extension, an enhancement, an evolution of the original, rather than a mere duplication—something that's inherently impossible. Recalling therein the lessons and insights garnered in the second chapter, this challenge underscores the need for a dynamic synergy between the realms, where the digital experience is not a mere replica but a unique and enriched iteration that resonates with both the heritage and expectations of the audience.

This brings forth a pivotal question: how can the immersive and interactive elements of the original exhibition be faithfully recreated in the digital sphere? How can the narrative thread that seamlessly weaves through the physical experience be artfully translated into a meaningful digital journey?

Hybrid Exhibitions:

- A hybrid exhibition can be understood as an intermediate state between traditional physical exhibitions and fully digital ones. It always involves the application of digital technology to a certain extent, but does not reach the complexity of a full digital exhibition;
- Hybrid exhibitions often blend physical artifacts with digital enhancements, offering visitors a unique and engaging experience that bridges the gap between the physical and digital realms. Thus, their exhibits or their curatorial design may include videos, touchscreens, or projections, or even augmented reality (AR) applications, immersive experiences, and more. It always involves the application of digital technology to a certain extent, yet still not reaching the complexity of a full digital exhibition.

Overview of Digital Assets Creation and Potential Challenges:

Hybrid exhibitions, bridging the physical and digital worlds, present a moderate preservation challenge. They often possess certain assets that already exist in digital formats, which represent a sort of starting point. Preserving these assets involves ensuring their continued accessibility and functionality, which is vital for maintaining the exhibition's immersive character.

However, the true essence of hybrid exhibitions resides in their ability to seamlessly blend physical and digital components, and here lies their true challenge. Preserving this harmony requires a meticulous and curated integration of the two, adapting them to each other, while enhancing the

overall experience. This entails a thoughtful orchestration to offer a cohesive, reasonable, and enhanced encounter for the audience.

Virtual Exhibitions:

- Virtual exhibitions transcend the boundaries of physical space entirely, existing solely in the digital realm. They utilize web platforms, virtual reality (VR), and other digital technologies to create immersive online environments.
- The complexity of virtual exhibitions can vary widely, from straightforward web-based displays accessible on standard devices to more sophisticated experiences designed for immersive engagement through VR headsets and augmented reality (AR) applications.
- Visitors can navigate virtual galleries, explore 3D models of artifacts, and access curated content from the comfort of their devices.
- Virtual exhibitions have the great advantage of opening up new avenues for global accessibility and interactivity, enabling users to experience - in a manner that suits their preferences and technological resources - art, culture, and history from anywhere in the world.

Overview of Digital Assets Creation and Potential Challenges:

Virtual exhibitions, existing solely in the digital domain, present a contrasting scenario. They often come with a head start in terms of digital assets, as their very nature involves the use of digital technology. In this context, the minimum requirements for digital preservation are typically already in place, given the inherently digital nature of the exhibition. However, this doesn't exempt them from other potential challenges, like long-term accessibility and technological adaptability, as I will discuss in more depth in the following paragraphs.

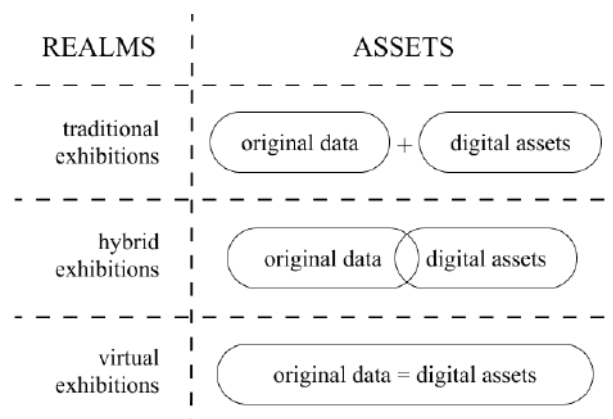


Figure 18, Visualization of the three realms and their assets' natures.

After completing the necessary preliminary assessments for digital preservation, the subsequent phase involves transitioning into the digital realm and implementing the required steps of the process. In order to derive these requisite stages applicable to all digital preservation level goals, the ARCO methodology (White, 2004) and the approach implemented by Pervolarakis, Z. et al (2022) have been identified as key references in the existing literature.

The ARCO pipeline is mainly based on a process of digitizing, managing, and presenting artifacts in virtual exhibitions using the ARCO system, a more comprehensive tool chain. The following steps outline the overall final process:

1. Content Production/Digitization: the acquisition of multimedia data, including 3D modeling of artifacts;
2. Refinement: processes to enhance content quality and accuracy;
3. Content Collection and Management: database storage, management, and organization of the digital artifacts into collections for display virtual exhibitions;
4. Contextualization: organizing the artifacts within exhibition spaces;
5. Visualization: visualization of the digital representations of virtual exhibitions, including web-based visualization, where 2D web pages with embedded 3D models and multimedia objects can be accessed remotely over the internet as well as 3D galleries that can be visualized in a web browser or through augmented reality interfaces;
6. Interactivity: establishment of interactive features for users to engage with the virtual exhibitions;
7. Accessibility and Commerce: to make virtual exhibitions more accessible to a wider audience. It allows for physical access to difficult-to-reach locations, intellectual access by enabling users to choose their viewpoints, remote access for schools and researchers, and psychological access by providing a sensuous exploration of the artifacts;
8. Customization: flexibility and customization options for both small and large museums to select components and build a bespoke system suited to their specific needs;
9. Standards and Interoperability: to integrate different components and technologies seamlessly, ensuring compatibility and ease of use.

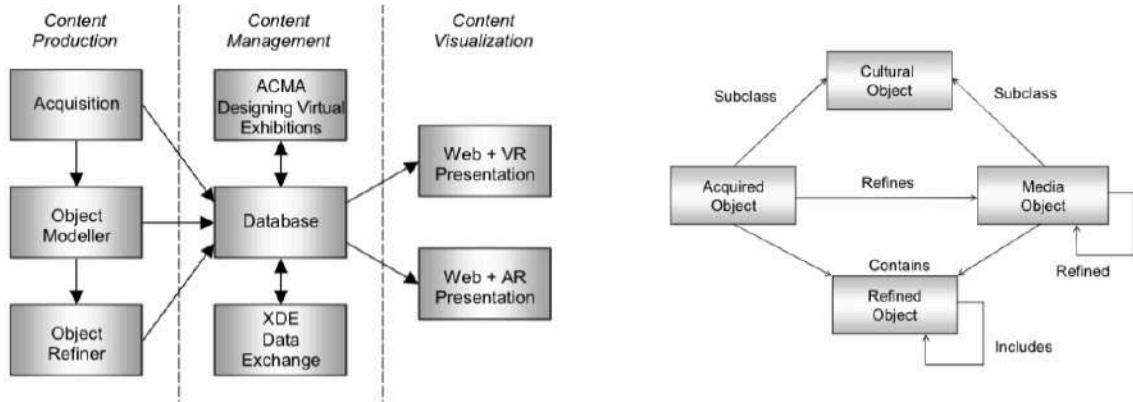


Figure 19, The ARCO System Architecture (on the left); the ARCO Data Model (on the right).

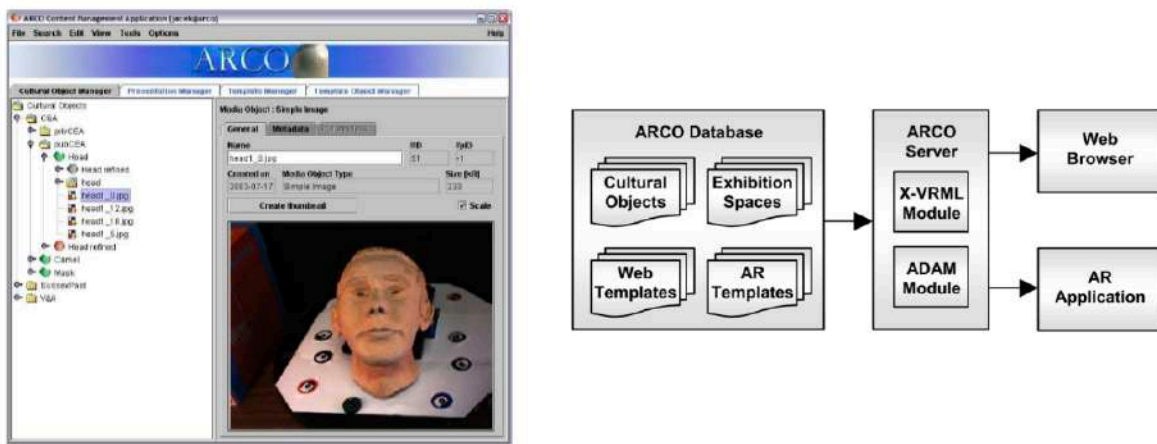


Figure 20, the ARCO Content Management Application (on the left); the ARCO visualization architecture (on the right).

In 2022, drawing from the ARCO example, Pervolarakis, Z. et al. presented the following methodology for digital preservation of temporary exhibitions which mainly involved the employment of the Invisible Museum platform:

1. Documentation Collection: The collection of detailed documentation of the exhibition to be preserved, including pre-existing digital assets such as photographs, exhibition catalogs, and other digital materials. On-site documentation is also conducted to capture elements of the exhibition that lack digital records. Additionally, 3D reconstructions of physical artifacts are performed using non-intrusive methods like photogrammetry and lidar-based 3D scanning. This step results in a collection of digital assets that will undergo digital curation.
2. Decision on Exhibition Environment: At this stage, a decision is made regarding the virtual exhibition (VE) environment, either by replicating the physical exhibition or creating a new digital architectural setting. For the former, the original exhibition is digitized while it is still ongoing using a combination of 3D digitization technologies, with architectural laser scanning being a prominent choice. The results of digitization undergo further processing, including the synthesis of various scans to create a synthetic model of the exhibition, and the

optimization of 3D models for real-time rendering on the web and in virtual reality (VR). For the latter option, the digital exhibition design is performed online, facilitated by the exhibition designer of the Invisible Museum platform, resulting in a 3D digital model of the exhibition.

3. Digital Curation: All the collected digital documentation is curated. This involves integrating digital assets into the authoring platform and curating individual exhibits. Curated exhibits contain not only the visual and descriptive content but also social and historical information, alternative digital representations of their documentation, and information about their physical constraints and size within the virtual space. Multiple translations of information can be provided to cater to a diverse audience.
4. Exhibition Curation in Digital Form: The digital curation process continues, focusing on the selection and placement of digital exhibits within the digital exhibition. For this purpose, the researchers employ the exhibition designer provided by the Invisible Museum platform.
5. Online Publication: The final step involves making the exhibition available online in alternative forms. This is achieved by publishing the exhibition and selecting from various supported rendering modalities, which can include 3D, VR 3D, and online browsing.

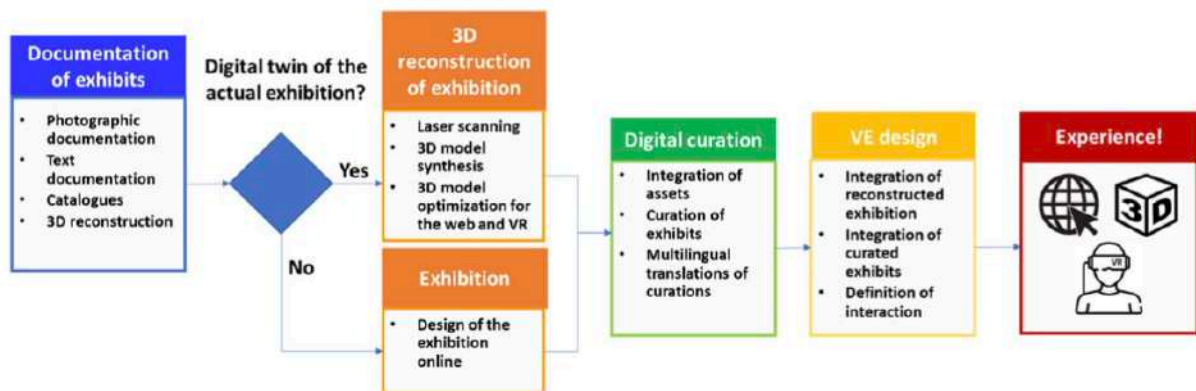


Figure 21, Methodology for the preservation of temporal exhibitions as proposed by Pervolarakis, Z. et al (2022).

Recapitulating all the steps thus far in this chapter, it is possible to start delineating a novel abstract pipeline for the digital preservation of temporary exhibitions, taking of course into account its two precedents just mentioned. This generalized pipeline provides a more flexible framework that can be adapted to the specific requirements and objectives of different digital preservation levels.

1. Preliminary Assessments:

The process commences with a thorough evaluation of the exhibition - or set of exhibitions in the schema of a greater endeavor - designated for preservation and of the institution leading this stewardship.

This initial evaluation serves as the foundation for the entire preservation effort. It involves an examination of the institution's mission, available resources, and existing assets. This includes an assessment of the software and hardware currently in use, consideration of budgetary constraints, and an estimation of the institution's expertise and potential opportunities for collaboration with stakeholders and partners.

2. Digital Preservation Goal Alignment:

Based on the preliminary assessments, the preservation team identifies the most appropriate digital preservation objective to pursue. This phase requires a critical decision-making process: should digital preservation meet minimum requirements, providing just an essential documentation, or should it strive for a full-fledged Digital Twin? The chosen goal will reflect the feasibility and desirability of the overall preservation endeavor. The three main levels identified, which will then dictate the complexity of the following steps, are:

Minimum Requirements:

At this initial stage, the focus is on achieving the minimum threshold for digital preservation. The primary objective is the creation of a basic yet comprehensive digital catalog of all exhibition assets in order to preserve its memory. This foundational layer sets the stage for more advanced preservation efforts, allowing institutions to customize their choices based on their unique resources and circumstances.

Overall, the resource demands at this preservation level are relatively straightforward and modest, focusing on efficient data collection practices and the utilization of existing tools and platforms. Institutions can build upon their established online presence to create a dedicated repository for exhibition records, enhancing, then, this “bidimensional” representation.

Intermediate:

The intermediate level occupies the space between the minimum requirements and the Digital Twin, allowing institutions to significantly enhance their digital asset collection and preservation efforts. Here, they can enrich their project by incorporating multimedia assets for a more comprehensive understanding of the exhibition. Also, advanced metadata management and deeper visitor engagement integration could be potentially integrated to this level, fostering enhanced data accessibility and interactivity. At this level, the preservation process and result's complexity rise yet never fully reach what is possibly achievable through the Digital Twin.

Digital Twin:

The Digital Twin represents the metaphorical pinnacle of digital preservation. At this level, institutions construct a complete 3D digital representation of the entire physical exhibition, down to detailed 3D models of each exhibit and the exhibition space itself. It offers visitors an immersive and interactive experience closely replicating the physical one and its “specialized communication system” as much as technologically feasible, requiring substantial investments in terms of time, effort, tools, and technological infrastructure.

3. Documentation Collection and Assets Digitization:

With the preservation goal established, the focus shifts to the intricate process of documentation. This phase involves:

1. The documentation of all exhibition data, encompassing textual and visual information about exhibits, spaces, curatorial elements, individuals, and their interconnections;
2. The creation of all the related digital assets, ranging from metadata, images, 3D models, and multimedia content, and more, derived from the starting data collected.

Additionally, especially when dealing with the creation of complex digital assets, including 3D models and 3D reconstructions, it is imperative to establish legally conforming agreements with all parties involved at this stage. This ensures clarity and legal compliance in the creation and usage of these assets throughout the rest of the preservation process.

To achieve a comprehensive set of documentation, meticulous record-keeping is essential throughout the entire lifecycle of the exhibition. This commitment to consistent data collection should begin during the planning stage of the exhibition, covering initial information, curatorial notes, provenance details, and more. It should extend through the implementation and display

phases, involving the tracking of changes, data updates, image capture, and so on, and continue into post-exhibition activities such as reviews and online engagement.

In the contemporary context, even for traditional physical exhibitions, a substantial amount of collaboration in exhibition design, management, and setup takes place online through digital platforms and tools, resulting in certain materials already being available in a digital format. Additionally, given the nature of the exhibition's assets, it is crucial to assess the availability of existing data that can be repurposed from open-source projects like digital libraries and catalogs. Collaboration with stakeholders and preservation project partners, particularly in the case of hybrid exhibitions, further enriches the resource pool for digital preservation. Depending on the preservation level, digitization efforts may vary:

Minimum Requirement:

Prioritize the collection of fundamental data for all core elements to create a foundational representation of the exhibition, which entails documenting crucial textual and visual information about the exhibits, spaces, curatorial elements, and personnel involved, providing a basic understanding of the exhibition.

In terms of textual data, place an emphasis on capturing essential metadata, including titles, descriptions, and any available provenance details to accompany the visual content. For visual references, ensure the inclusion of high-quality images that cover all the exhibits, with a specific focus on capturing the spatial layouts. This approach helps convey the exhibition's overall environment and the role of curatorial elements in shaping the visitor's experience.

Additionally, make sure to document basic visitor information, such as logs, counts, and any available feedback or interaction records about their post-exhibition online activities, possibly through a simple set of links. This data offers valuable insights into the level of engagement and impact for further enriching the understanding of visitor interactions with the exhibition.

The tools and resource demanded at this level are relatively straightforward and modest, focusing on efficient data collection practices and the utilization of existing tools and platforms, especially for data storage and organization. High-quality images of exhibits, spaces, and curatorial elements can be ensured using digital cameras or smartphones with integrated good cameras.

Intermediate Level:

Enhance the basic information, such as the creation of immersive panoramic views of the exhibition space using 360-degree photography and the recording of videos offering virtual tours. These additions provide visitors with dynamic and, if possible, immersive experiences, resulting in a more comprehensive understanding of the exhibition's layout and overall experience. Advanced metadata management should also be contemplated to facilitate complex queries and semantic data linking.

Furthermore, visitor engagement can be deepened with real-time aggregation of visitor-generated content from social media platforms, creating dedicated sections for collecting feedback and critical reviews. These initiatives contribute to a richer and more interactive visitor experience.

At this intermediate level, various tools and technologies come into play to enhance the visitor's experience and the management of the digital assets. These could include: survey or feedback tools; 360-degree photography equipment; video recording equipment for creating video or virtual tours, capable of recording in high resolution and capturing smooth, steady video; 3D scanning tools; etc.

Digital Twin:

Focus on the comprehensive documentation and acquisition of 3D virtual reconstructions of exhibits, spaces, and curatorial elements. Cutting-edge techniques and tools are employed to create highly detailed and immersive digital representations to be later refined and optimized.

A combination of hardware and software tools are essential to create 3D reconstructions of exhibits and exhibition spaces. Hardware will encompass:

- 3D Scanners to capture the physical geometry and texture of objects and spaces. Depending on the scale and precision needed, different types of 3D scanners can be employed, such as handheld scanners or laser scanners;
- Photographic Equipment such as high-quality cameras to capture detailed images. This includes digital single-lens reflex (DSLR) cameras and, in some cases, specialized cameras for capturing high-resolution textures;
- Lighting Equipment, as proper lighting, like continuous LED lights, to achieve consistent and well-lit photographs, which are essential for photogrammetry;
- Sturdy tripods and mounting stands to maintain a stable position for cameras and scanners to capture images and data accurately;

- Computing Hardware such as high-performance computers or workstations for processing large datasets generated by 3D scanning and photogrammetry, with sufficient memory and processing power.

Software may include:

- 3D Scanning Software, like proprietary software provided by the scanner manufacturer or open-source alternatives, to operate 3D scanners and generate 3D models;
- Photogrammetry Software, proprietary options such as Agisoft Metashape and RealityCapture, or open-source ones like 3DF Zephyr and Meshroom, to process and reconstruct 3D models from photographs;
- 3D Modeling and Editing Software like Blender or Autodesk Maya for refining and editing 3D models, enhancing textures, and optimizing models for real-time display;

It is important to note that the specific tools and software used may vary, and a balance between open-source and proprietary tools may be employed to meet specific project needs. The choice of equipment and software should be guided by the goals and resources of the institution and the exhibition in question.

4. Digital Assets Curation:

Curate all the collected digital assets. This involves organizing, optimizing and enhancing digital assets before their full integration. This passage is especially crucial when aiming at a full digital replica of the experience, as 3D acquisitions of exhibits, curatorial elements and spaces will necessitate additional curation.

Advanced metadata curation involves the adoption of Linked Open Data (LOD) principles ensures that Cultural Heritage data follows open formats and licenses, as well as aligns with the FAIR (Findable, Accessible, Interoperable, Reusable) principles:

- Findable: Metadata should be designed to make digital assets easily discoverable through descriptive and searchable information.
- Accessible: Metadata should provide clear details on how to access the digital assets, ensuring they are readily available.
- Interoperable: Metadata should be structured in a standardized format, allowing for compatibility with various systems and platforms.

- Reusable: Metadata should be comprehensive and well-documented to facilitate the reuse of digital assets.

Standardization can, indeed, play a crucial role in ensuring that the digital assets are well-structured, consistent, and easily accessible. The use of ontologies and metadata schemas, such as the CIDOC-CRM, FRBR, and EDM, ensures cross-cultural and multilingual compatibility and that knowledge representation adheres to well-established domain standards. These standards facilitate semantic interoperability, enabling meaningful representation of exhibits in their sociohistorical contexts. The same attention for standardization alignment should be applied in the context of file and object formats, like for example glTF for 3D models, to ensure interoperability with 3D platforms and services and to facilitate re-use and integration of licensing information.

For 3D models, especially those of exhibits, curatorial elements, and spaces, optimization is necessary to ensure efficient online presentation and user experience. This may include meshes and textures optimization to reduce complexity and the size and loading times of 3D models without sacrificing visual quality and fidelity. 3D rendering engines like Unity or Unreal Engine could be employed to render 3D models and consequently create interactive exhibitions in a virtual space as they also provide the necessary tools for lighting, shading, animation, and interactivity in the virtual environment.

5. Exhibition Curation in Digital Form:

Continuation of curation, focusing on the placement and arrangement of digital assets within the digital exhibition environment chosen. The choice of tools and platforms for this step depends on the preservation level's complexity and requirements, ranging from the reuse of existing resources to the creation of new ones. In this phase, depending on the goal, hardware will for sure include platforms to host the digital exhibition and powerful server to store data. This phase is pivotal for achieving interactivity and customization based on the specific goals of the digital exhibition.

6. Publishing and Accessibility:

Make the digital exhibition available online in diverse forms, ensuring accessibility to a wide audience. These alternative forms may range from web-based interfaces to even virtual reality experiences, ultimately providing the public with the opportunity to engage with the preserved exhibition.

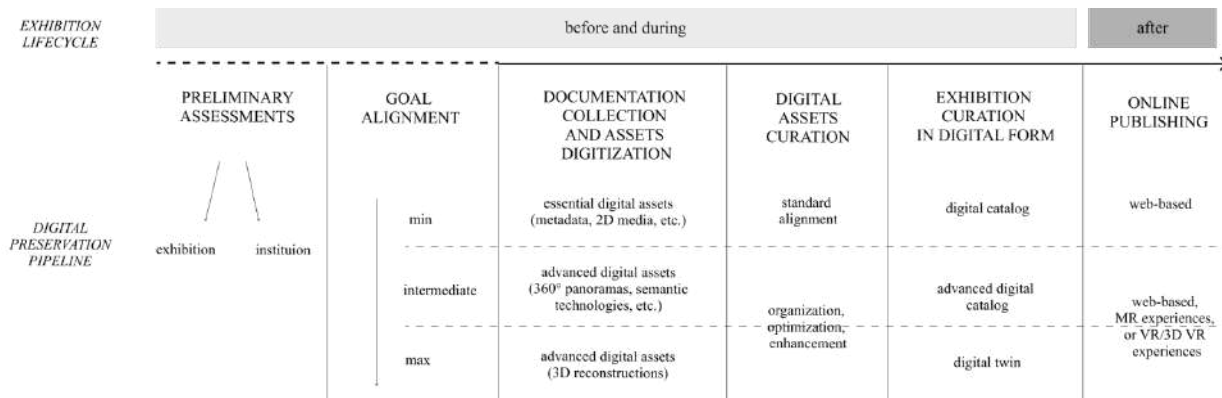


Figure 22, Digital preservation pipeline aligned with the exhibition lifecycle phases.

3.3 Potential Challenges, Open Issues, and Future Scenarios

Thus far, only the primary challenges that act as barriers to the digital preservation of exhibitions have been addressed. Instead, embarking on these kinds of endeavors opens the door to a new array of potential obstacles, each contingent on the complexity of the chosen preservation goal. Institutions may opt for different objectives to pursue, and with each level comes a unique set of challenges, especially when dealing with a full reconstruction (Gattet et al., 2015; Di Paola et al., 2022; Farella et al., 2022).

Even if they have been already briefly mentioned, the purpose of this chapter is, then, to navigate them in more detail, emphasizing the difference between potential barriers and open issues in the CH field. Challenges are the immediate hurdles that organizations encounter as they embark on their digital preservation journeys; they are not insurmountable yet require careful consideration, strategic planning, and collaboration to ensure the success of these preservation solutions. Open issues, on the other hand, are enigmatic territories where solutions remain elusive, and the field is still on a quest for answers.

To begin, a proper categorization is the first step to take in order to provide clarity and insight into the potential challenges' realm. While each pain point will be addressed individually, it's crucial to understand their interconnected nature. Like dominoes in a chain reaction, the presence or resolution of one of these factors often triggers or influences another. A misstep in any one stage of the process can have ripple effects throughout the entire preservation endeavor. Moreover, to offer a more proper examination, firstly, I will discuss those challenges that fall within the purview of expertise, tackling them chronologically as encountered during the various stages of the pipeline.

Secondly, I will also take into consideration those barriers that extend beyond my core expertise. These mainly encompass budgetary constraints and legal aspects, which permeate the entire preservation process, necessitating to be at least briefly mentioned given their reach.

Documentation Collection Challenges:

Once aligned with the envisioned preservation goal, the first set of pain points that an institution may most likely encounter are related to the acquisition phase, where mainly logistical considerations and material-related complexities can create some friction.

1. Logistical Challenges:

The logistical hurdles usually trace back to time constraints and space limitations. Exhibitions, often temporary by nature, impose significant temporal limitations on this process, urging to capture complex assets within tight schedules. The acquisition of both exhibits and exhibition spaces is also often constrained by various factors, including limited access to electrical outlets, unsuitable lighting conditions, restricted maneuvering space for the digitization process, and more. In some instances, objects were immovable or too fragile for unrestricted handling, necessitating careful supervision during any interaction.

Addressing these challenges involves careful planning, a time-efficient approach, and especially the avoidance or limitation of on-site digitization during exhibitions whenever feasible. Ideally, exhibits and spaces are already digitized, with the final phase of digital curation involving their integration and the incorporation of all curatorial elements for comprehensive preservation. An example in this regard is the model described by Pervolarakis, Z. et al., where the “space” element can be frequently reused as it appears to be the designated environment for exhibitions. Once digitally captured, this asset doesn't require repetitive digitization but can be efficiently reused and customized to accommodate new exhibits and curatorial elements, minimizing the need for redundant data acquisition and optimizing the preservation process.

2. Material-related Challenges:

Cultural heritage objects and exhibition spaces can be constructed from a multitude of materials, some of which present considerable challenges for digitization. Surfaces with specular components, such as black, glossy, or transparent materials, can significantly complicate the optical response of

detection instruments. Furthermore, these material-related complexities also manifest in the "Space" element, as not all exhibitions occur in pristine "white cube" environments. They can take place in diverse surroundings with varying levels of environmental complexity, all of which need to be accurately replicated in a digital 3D model and introduce similar material-related issues as encountered with exhibits.

There are also situations where logistical constraints intersect with material complexity, such as with the typical exhibitor glass cases or when dealing with remarkable dimensions. In both cases, adequate measures in terms of set up or technology must be taken.

Overall, in overcoming these material-related challenges, having the right hardware and software is crucial, but more importantly, the presence of the right expertise, guided by established frameworks and best practices, is indispensable. Meanwhile, the field of Cultural Heritage preservation continues to investigate and develop increasingly efficient solutions to address these complexities comprehensively.

Digital Asset Curation Challenges:

In this phase, several significant challenges, especially open issues, emerge, making the presence of the right expertise and personnel indispensable. These challenges primarily revolve around data management and long-term preservation, both of which are critical for the sustainable preservation of cultural exhibitions.

1. **Data Management and Optimization:** A key challenge in this phase is the efficient management and optimization of digital assets. 3D models and other multimedia content can be quite large and resource-intensive, especially when aiming for online fruition. One practical solution could be to maintain two versions of the assets: one high-resolution version for preservation and one optimized version for online access, which however pose other challenges storage-wise. This approach balances the need for high-quality preservation with the requirement for efficient online delivery.
2. **Long-Term Preservation:** Ensuring the long-term preservation of digital assets and data related to cultural exhibitions is a critical aspect of the curation phase. It involves considerations such as data formats, storage technologies, metadata management, and data integrity. One of the primary concerns in long-term preservation is the risk of data

degradation, obsolescence, or loss. Strategies for data migration, format conversion, and periodic integrity checks are essential to mitigate these risks and ensure that the cultural assets remain accessible for future generations.

While these challenges are well-recognized, there is no one-size-fits-all solution to long-term preservation. The field is still actively exploring how to best address and mitigate these issues as achieving effective long-term preservation is an ongoing and evolving process that requires a multidisciplinary approach, drawing from the fields of digital archiving, information science, and Cultural Heritage preservation.

Exhibition Curation in Digital Form Challenges:

As digital preservation efforts culminate in the exhibition curation phase for future publication, several design-related challenges may arise. First and foremost, the integration complexity. Integrating various digital assets, interactive features, multimedia content, and curatorial elements into a cohesive digital exhibition can be intricate. Ensuring that all components work seamlessly together and provide a consistent and engaging visitor experience is a significant design challenge at already an intermediate level. Going further into digital twins' realm, designing an engaging and interactive digital exhibition for visitors can add another layer of difficulties especially when trying to reproduce fully and as faithfully as possible that “specialized communication system”, the social and interactive elements of events like exhibitions in the digital realm. Nowadays, feasible solutions currently in phase of exploration in the Cultural Heritage field involve multi-user VR environments and Metaverse options.

Extending beyond (“meta”) traditional virtual reality (VR), the idea of the Metaverse introduces an interconnected, persistent, shared 3D virtual space, forming a perceived virtual universe that bridges all virtual worlds and a future iteration of the Internet (Moneta, 2020; Zhang et al., 2022). This resulting parallel digital universe represents an environment where users can collectively participate, fostering a sense of shared experiences akin to the physical ones, like the case of exhibitions. Furthermore, the metaverse has already found practical applications in education and architecture, broadening its reach beyond entertainment. In educational contexts, it has been employed to document and share knowledge about historic buildings, with a primary focus on existing heritage sites (Gaafar, 2021).

Notably, researchers like Manovich and Douglas (2021) have showcased examples of how metaverse platforms can be instrumental in preserving lost Cultural Heritage. These applications range from re-creating vanished heritage sites and digitizing cultural artifacts to crafting interactive and immersive narratives. Moreover, the Metaverse fosters collaborative efforts in the preservation and restoration of Cultural Heritage sites and artifacts, enabling experts from different parts of the world to join forces in these crucial endeavors.

A recent and notable exemplar is the work by Alkhatib et al., “Bringing Back Lost Heritage into Life by 3D Reconstruction in Metaverse and Virtual Environments: The Case Study of Palmyra, Syria” (2023). This study showcases how this technology can be harnessed to reconstruct, preserve and promote lost heritage sites. The specific case study focused on the Palmyra Roman theater in Syria, which had been destroyed during the war, causing irreparable harm to its physical structure and historical significance. The goal of the project was to digitally reconstruct the site using 3D reconstruction techniques and optimize the model for VR and Metaverse platforms, allowing users to explore and experience the lost theater in its original form in a virtual environment. The project presented a range of challenges, including optimizing the digital model’s complexity for the Metaverse, and fine-tuning textures and materials to provide a realistic experience. Despite these difficulties, this study’s outcomes highlight the exciting possibilities of these technologies regarding multiple users’ fruition and experience in real time of a digitally reconstructed world, demonstrating its importance in the field of CH preservation, for lost heritage, in particular.



Figure 23, The final output of the Palmyra theater inside the Metaverse platform (on the left); on the right: example of navigation inside the reconstructed theater with an avatar (on the right).

However, embracing the Metaverse, especially in the Cultural Heritage field, is still in its infancy. It faces several challenges, including the general public's limited familiarity with the hardware necessary for metaverse experiences and its associated high costs; ethical and legal considerations, such as privacy, data usage, platform ownership, and potential shutdowns, present additional hurdles to overcome (Alkhatib, Y.J., 2023). Despite these challenges, the potential of the metaverse

in the realms of Cultural Heritage, research, and education is evident, offering an array of innovative scenarios and untapped opportunities for further exploration.

Online Publishing Challenges:

In the final phase, there are significant challenges associated with accessibility and hardware restrictions. Although the potential of immersive technologies, such as VR and the Metaverse, is vast, one significant issue is guaranteeing equal access to these experiences. The specific hardware required for complete VR immersion, such as high-end headsets or powerful computing systems, is not easily accessible and widely available and deployed. This constraint may result in discrepancies in the audience's capacity to engage with the reconstructed digital exhibitions. As a consequence, institutions and scholars should keep exploring alternative approaches to interaction and engagement that do not depend predominantly on specialized hardware.

Other Challenges:

Lastly, as previously underlined, it would be remiss not to, at least, acknowledge two of the predominant challenges consistently identified by experts in interviews and through the examination of notable cases like the Invisible Museum example: budget constraints and legal complexities.

The endeavor of creating and sustaining an advanced digital preservation project, especially a Digital Twin of an exhibition, can be financially demanding for a variety of reasons. Expenses encompass personnel with specialized expertise, acquisition equipment (notably 3D scanning devices), the establishment of the requisite technological infrastructure for storage, and ongoing maintenance, and more, all of which collectively contribute to a considerable financial burden. While I've already recognized that the intricacies of these matters may extend beyond my expertise, a few strategic measures can be undertaken to alleviate the economic burden associated with these digital preservation endeavors.

Conducting a thorough preliminary assessment of institutional resources and objectives as already stated is imperative and, in this context, all the more reason, because it also involves evaluating the potential for reusing of existing technologies and data assets to maximize feasibility and reduce the financial burden. This step may additionally include exploring a diverse range of funding options is essential to secure the necessary resources in support of the overarching preservation objectives.

This can include seeking grants, sponsorships, and donations to bolster financial support. Moreover, engaging in collaborative partnerships with other museums and cultural institutions can effectively disperse the financial responsibilities associated with establishing and maintaining a digital library of 3D exhibit models, a crucial component of these digital activities.

In addition to the economic challenges, legal considerations also are another critical pain point in the realm of digital preservation, as, once again, shown by the Invisible Museum's example. At various levels of digital preservation, copyright concerns loom large, as exhibitions frequently incorporate various types of copyrighted materials. Gaining permission to employ such materials within a digitalization project is a complex endeavor to be tackled as soon as possible. Moreover, when aiming for the highest level of digital preservation goals, such as the creation of digital twins, broader intellectual property considerations may come to the forefront. These replicas can, in fact, raise complex questions regarding ownership and usage rights. Failure to address these issues adequately can lead to subsequent disputes over the rightful possessors of the rights to employ, distribute, or modify the digital twin. Generally speaking, and according to the discipline, the validity of an intellectual property claim largely depends on the level of creativity and originality embedded in the creation of the digital twin.

To adeptly navigate this intricate legal landscape, acquiring essential permissions and licenses from the artists and creators involved is a fundamental step to be address as soon as feasible. Incorporating clauses in contracts with artists and contributors, explicitly granting permission for the reproduction and display of their works in digital formats, becomes an imperative practice at the very preliminary stages of these activities. Additionally, it is essential to recognize that intellectual property laws can vary significantly by jurisdiction, introducing further complexity. Thus, collaborating with legal experts who specialize in the field and seeking their counsel before proceeding is advisable to ensure full compliance with copyright laws and regulations. Moreover, to make this process easier for institutions, the establishment of national or supra-institutional bodies with legal experts specialized in Cultural Heritage could offer a viable solution. These entities could provide guidance and assistance in navigating these challenges, thus facilitating the field's compliance with copyright and intellectual property laws.

To conclude, in both the economic and the legal case, the solutions just discussed are merely suggestions to be more in depth analyzed and ponder elsewhere.

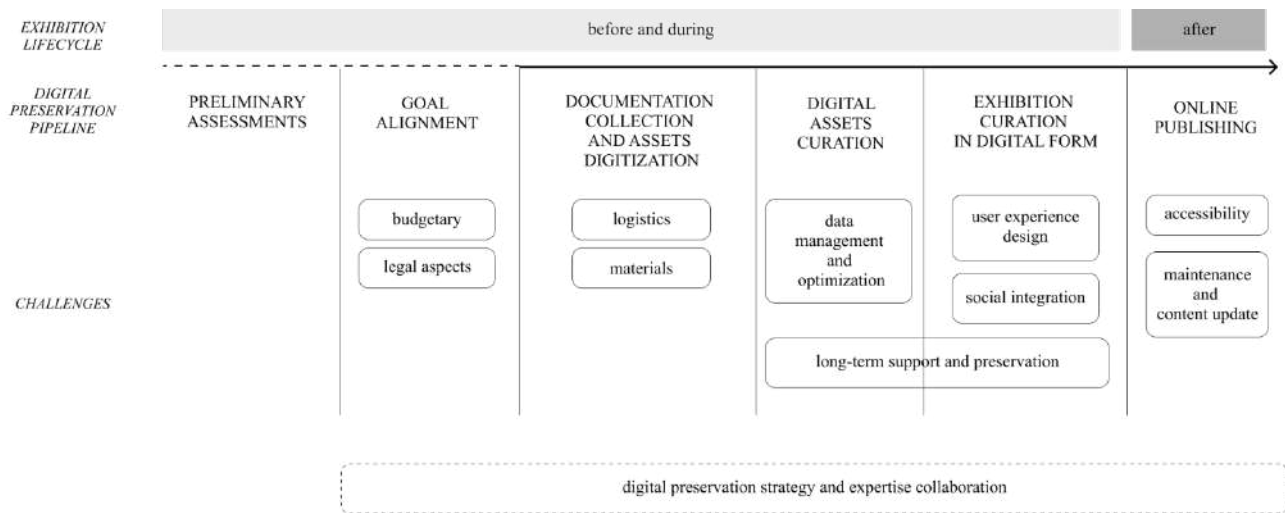


Figure 24, Visualization of the potential challenges and open issues aligned with the exhibition lifecycle and digital preservation pipeline.

3.4 Conclusions

From the beginning, it became clear that preserving temporary exhibitions in the digital era was an intricate task, demanding distancing from linear procedures. This required a fundamental change in approach, implementing a basic bottom-up technique resulting in the redefinition of fundamental concepts. Time was an essential dimension recognised as a crucial aspect of this shift. Temporal consideration acknowledges that exhibitions occur within specific, fleeting moments and are subject to continual evolution. This perspective has necessitated a transformation of the presented framework to accommodate the dynamic nature of temporary exhibitions.

This revised definition, both conceptually and practically, had a significant impact on the preservation approach. Incorporating time resulted in aligning each phase of the exhibition cycle with a corresponding stage in the preservation pipeline, and vice versa. This alignment effectively integrated preservation into exhibition planning, creation, and post-exhibition phases, as it is crucial to ensure that preservation methods are strategic and not reactive.

This angle revealed a pragmatic standpoint that deals with concrete issues often overlooked, providing a structured approach to recognize, anticipate and resolve potential complexities. Preservation transcends scholarly theories and manuals, requiring answers for tangible obstacles encountered by institutions daily. This study, indeed, investigated the most common and important variables and challenges of digital preservation, providing viable solutions and recommendations

for establishments undertaking such projects. The focus was, then, on transcending theory to offer practical advice.

A key strength of this work is the creation of a visual representation that captures the framework's essence. This graphic aligns all the elements taken thus far into consideration - the digital preservation goals, preservation pipeline, challenges encountered, and exhibition lifecycle - to provide a practical tool for institutions to delineate their preservation strategies, cultivating a profound comprehension of where the challenges may arise and how to tackle them efficaciously.

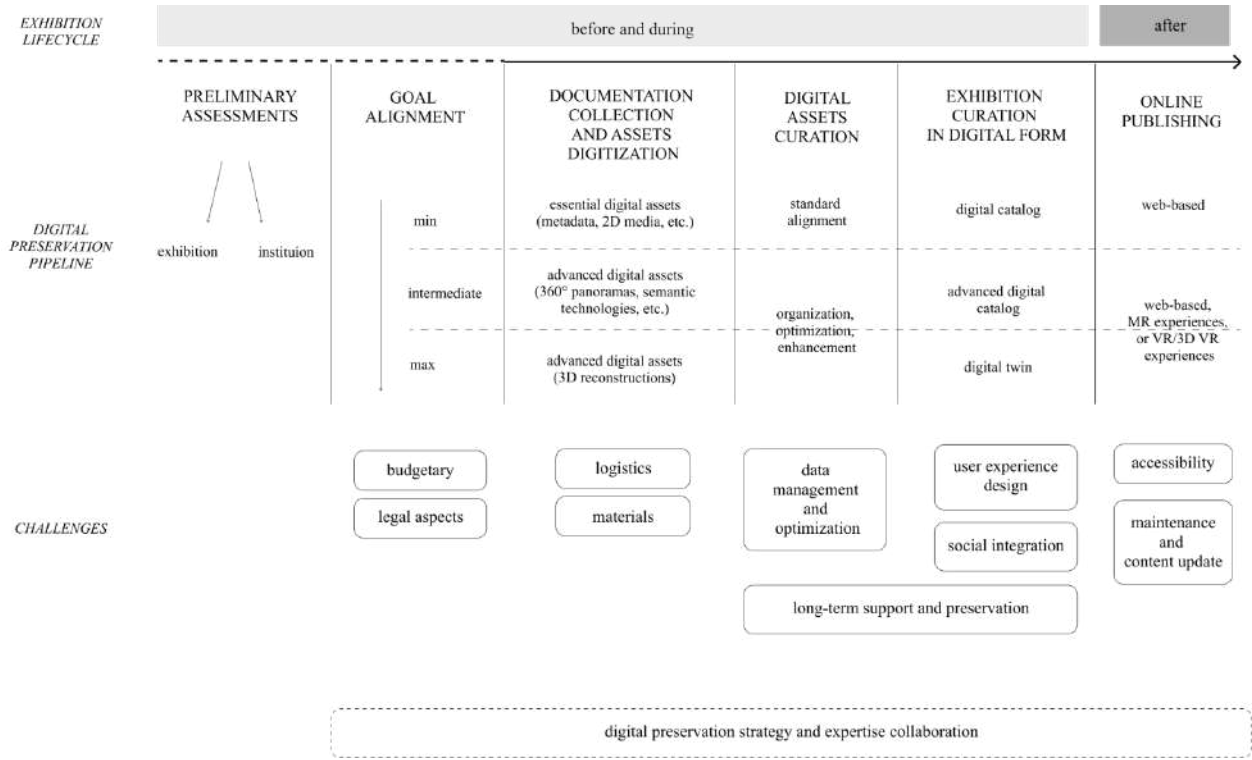


Figure 25, Framework's final visualization.

To conclude, this chapter signifies the apex of my research, whilst also paving the way for future prospects and discourse regarding digital preservation of temporary exhibitions. Numerous unresolved components necessitate further investigation and scrutiny, demanding more resources and expertise beyond the extent of this study and my reach. It is therefore my hope that this framework and the insights it offers will serve as an advocacy for the niche field and will encourage cultural institutions to embrace digital preservation with more confidence.

4 CASE STUDY: THE ALDROVANDI EXPERIENCE

This chapter concentrates on the case study of the Aldrovandi exhibition, which represents a focal point of this inquiry. The examination is guided by the structured framework developed and refined in this thesis (Chapter 3), and based on this knowledge gained from the previous chapters, the goal is to reveal all the complexities encountered in preserving and translating this exhibition in the digital domain. This chapter presents a chronological account of the Aldrovandi exhibition's digital transformation, as it explores the stages of the initiative and a comprehensive overview of the insights gained from my personal involvement and the collective efforts of the team up until now. Given that the project is still ongoing, the last section wraps up by looking at the next stages and how this work set to evolve.

4.1. Overview of the Ongoing Project

The Exhibition:

In accordance with the criteria set forth in the preceding chapter (3.2), the exhibition “The Other Renaissance: Ulisse Aldrovandi and the Wonders of the World” can be categorized as a hybrid exhibition. This attribution is grounded in the observation that the exhibition's core components show a modest degree of interactivity and achieve a seamless fusion of traditional and digital elements.

Within the extensive array of over 200 exhibits, digital media, in the form of videos, played a pivotal role in adding depth and contemporaneity to the overall visitor experience. These videos served various purposes, encompassing introductory presentations, the display of artworks not physically present at the exhibition, detailed analyses of selected artifacts, and even the creation of immersive ambient effects, both visual and sound.

Moreover, the exhibition's curatorial aspects and its interactions with the public were significantly enriched through an effective utilization of different digital means. For starters, visitors were granted access to an audio guide via a convenient QR code, which, in turn, unlocked a trove of supplementary educational content. This audio guide, indeed, functioned as a gateway to a deeper comprehension of the historical and scientific contexts underpinning the exhibition and its elements, while also offering guidance through the exhibition's rooms without imposing an overly too structured path.

In a concerted effort to foster a more participatory experience, the exhibition actively involved its visitors through surveys as simultaneously, the promotion of the exhibition featured the provision of additional educational content and activities online, particularly via the institutional social media channels. This multifaceted promotional approach, indeed, stemmed from the exhibition's role as a central component in the broader celebration of Aldrovandi's character, underscoring his significance within this larger undertaking.

Its overall cultural value and exceptional popularity, having drawn approximately 30,000 visitors, contributed to its inclusion in the wider CHANGES context. However, this choice was not solely rooted in these impressive numbers but was mainly guided by a more profound motivation. The exhibition was conceived with a visionary goal in mind – to introduce Ulisse Aldrovandi as a precursor of modern scholarly and scientific communication and dissemination. A central facet of his pioneering work, in fact, was his meticulous process of incorporating objects into illustrated volumes, underscoring the close relationship between art and science, and the many possibilities blossoming from their communication.

In striving for a digital representation of this exhibition, the team of experts involved in this initiative found a beautiful correspondence in that same 500-year-old idea of innovation and knowledge dissemination, but more advanced –a kind of legacy, its natural continuation. Thus, this project and its overall mission aim not only at enhancing the exhibition's cultural significance, but also imparting a deep moral message about the ongoing evolution of scholarly and scientific communication means.

Institution(s) and Collaborators:

The stewardship of this exhibition and its digital preservation involved various institutions and dedicated personnel. The SMA - il Sistema Museale d'Ateneo, in charge of its original curation, was supported in this endeavour by some of the entities within the CHANGES context, among which the University of Bologna itself was one of its major players.

As already touched upon in the introduction, the CHANGES initiative, short for “Cultural Heritage Active Innovation For Next-Gen Sustainable Society” encompasses diverse facets of Cultural Heritage (CH), tackled in nine thematic sub-projects, “Spokes”. Spoke 4, dedicated to the use of virtual technologies for the promotion, preservation, exploitation, and enhancement of Cultural

Heritage within museums and art collections, is the one where the Aldrovandi's exhibition has been specifically taken into consideration as case study for further exploration.

Goal:

The main objective, therefore, of this initiative has always been to achieve a comprehensive digital reconstruction of the Aldrovandi's exhibition and its experience. This ambitious endeavor involves building upon the digital twin of the event and establishing connections with the digital assets representing a wide array of items, encompassing both exhibits and curatorial elements spanning various formats, from 3D objects to multimedia content. The digital twin, representing the highest goal of digital preservation following the criteria of the framework therein discussed, served as the focal point of the whole effort. The currently ongoing work is aiming at thoughtfully organizing these digitized materials to ensure their future accessibility to a wide user base employing an array of devices, including home computers, smartphones, tablets, and VR headsets.

Considering that this preservation effort was embedded within/associated with/part of a broader research project, it also stemmed from exploring and addressing specific challenges intrinsic to the process in order to identify potential technologies, methodologies and solutions that could solve the main interrogatives and priorities of cultural institutions. To steer this undertaking, four central research questions (RQ1-RQ4) were thoughtfully formulated, each tackling a crucial aspect of the digital preservation journey.

- RQ1: The first research question revolved around the preservation and accessibility of temporary exhibitions, with a particular emphasis on how to faithfully capture the essence of the physical exhibition and replicate the visitor experience in the digital realm.
- RQ2: The second delved into the impact of environmental, temporal, and contextual factors, and how to assess and develop strategies for monitoring their effects on the final stored and visualized digital objects.
- RQ3: The third placed significant attention on the handling, acquisition, and processing of objects composed of unique and challenging materials, seeking to develop effective strategies for capturing their intricacies in the digital realm while ensuring a faithful representation.
- RQ4: The fourth and final research question explored the establishment of a seamless and well-structured data flow throughout the digital preservation journey, with the aim of increasing accessibility and usability for all.

It is worth, at this juncture, mentioning that an activity I participated in was a survey, which has been already briefly introduced earlier in this thesis in the methodology section (1.2). To explore the Aldrovandi preservation project comprehensively, the team also implemented a survey as a research strategy that is particularly relevant to better understand the depth and resonance of this effort on the general public. In this context, I collaborated with my fellow researcher Federica Bonifazi on her probe kit and questionnaire, which aimed to examine the extent to which the exhibition piqued the curiosity of its attendees and in what manner. The people involved in these activities were first year students of the Master's Degree in Digital Humanities and Digital Knowledge of the University of Bologna (Academic Year 2022-2023) as part of their curricular course in Interaction Media Design held by Professor Sofia Pescarin.

In this context, the survey was also instrumental in unveiling the public's perspectives on theme like preservation, memory, and relevance. We posed them the sequent three questions in this regard:

1. What do you expect Palazzo Poggi to do about the preservation and memory of this exhibition?
2. Is there something among what you saw that, in your opinion, should definitely be kept to preserve the memory of this exhibition?
3. And what is irrelevant and could be avoided?

These questions aimed to provide insights from non-experts users concerning institutional preservation efforts. It was our intention to discern whether there existed any disparities between the current preservation strategies employed and the public's understanding and expectations.



Figure 26, Survey's participants experiencing the exhibition, source: Federica Bonifazi.

The first question's answers were extremely relevant in this regard, as they revealed a diverse range of perspectives, with almost half of the participants demonstrating awareness of innovative techniques, including digital methods such as creating digital catalogs and leveraging the Metaverse for preserving the exhibition's memory.

ID	Answer
1	Moving to a metaverse.
3	I hope it will stay on a digital platform.
9	Storytelling in social which we could find after closing this exhibition.
10	I think it could create a catalog of the exhibition (both printed and digital) and maybe create a permanent online section dedicated to the exhibition.
13	I think Palazzo Poggi should preserve the memories and things in the artefacts. Also if this exhibition could be arranged virtually with preserved items shown in 3D format would be more interesting and engaging.
15	I expect Palazzo Poggi to preserve the memory of this exhibition in books and pamphlets, but it would be nice to build a virtual space dedicated to it.
25	I hope they manage to preserve it all, from the artifacts to the curatorial aspects. I would expect them to do it by exploiting some digital tool, like virtual environments or at least a very detailed website with videos and photos of it.
26	Make a virtual exhibition.

Table 2, Examples of relevant answers to the first question “What do you expect Palazzo Poggi to do about the preservation and memory of this exhibition?”.

Conversely, the remaining responses tended to emphasize more traditional preservation methods, such as printed materials or returning objects to their owners. Some other answers alluded to broader preservation goals, such as maintaining specific digital displays, digitizing maps, books, and portraits, or lamenting the potential loss of digital assets. This variation in responses highlights the different expectations and understandings of preservation among the surveyed participants.

ID	Answer
8	Try to preserve fascinating parts that will be useful for future generations.
23	Re-create it in the future.

24	Catalog, video recording, interviews with visitor, map to easily reconstruct the structure of the exhibition.
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Table 3, Other examples of answers to the first question “What do you expect Palazzo Poggi to do about the preservation and memory of this exhibition?”.

In the context of digital awareness, some of the answers to the second question (“Is there something among what you saw that, in your opinion, should definitely be kept to preserve the memory of this exhibition?”) were also remarkably relevant, highlighting the value of digital assets in enhancing the exhibition experience and aligning with the broader shift toward digital solutions.

ID	Answer
10	I would maintain some digital displays (very useful for explaining) and the section dedicated to the botanical books and prints.
16	I think the digitization of the maps, books and portraits as well as pictures of tools used for printing drawings would be useful; the interactive pictures would also be very interesting to see in a website.
24	It is a pity that many digital assets won't probably be displayed anymore. Some strategies should be developed to save and allow further access to this material.
26	3D models of the wax figures.

Table 4, Examples of answers to the second question “Is there something among what you saw that, in your opinion, should definitely be kept to preserve the memory of this exhibition?”.

Documentation and acquisition:

Moving on to the third phase of documentation collection, the primary focus was to acquire the entire collection on display as a starting point of the final Digital Twin creation. This involved capturing the multimedia content available to visitors and the physical spaces, which included the rooms where the exhibition was hosted.

This massive endeavor was accomplished thanks to the collaboration of six acquisition teams, the personnel of three museums and one library, and a specialized external group of technicians who assisted with the logistics, such as the removal and reinstalling of the display cases throughout the acquisition process. The institutions involved were:

- Five Departments of the University of Bologna (Architecture; Civil, Chemical, Environmental, and Materials Engineering; Classical Philology and Italian Studies; Cultural Heritage; History and Culture);
- The Digital Heritage Innovation Lab of CNR ISPC (Florence and Rome branches);

- The University of Bologna Museum Network;
- The Bologna University Library;
- The Archeological Museum of Bologna;
- The Medieval Civic Museum of Bologna.

To streamline the execution of the main needed tasks, these collaborating entities established in advance a comprehensive protocol to ensure an efficient workflow. Additionally, they harnessed Microsoft Sharepoint as a shared workspace for seamless communication and data sharing, all while adhering to stringent data protection regulations.

The initial phase of their work involved assessing the exhibition's items to prevent duplicated efforts and eliminate objects that had already been digitized in prior research projects. Subsequently, the project followed a well-defined pipeline, including the acquisition of the remaining pieces, then their process, modeling, optimization, and export using dedicated software tools, culminating in their upload to a Web-based framework (ATON).

Throughout this process, a meticulous progress tracking and documentation of pertinent metadata was systematic to guarantee the long-term preservation and accessibility of the digital assets. Key information recorded included details about the institution responsible for each activity, the individuals involved, the tools utilized, and the dates associated with each step of the process.

Alongside the tangible aspects of managing the physical exhibits and their acquisition process, a significant parallel effort was devoted to managing all the associated metadata. This step encompassed the comprehensive collection of data pertaining to the exhibition's objects, including essential attributes such as their inherent characteristics, origins, and subject classifications and sourcing bibliographic data from a diverse array of resources, such as the official exhibition catalog, curator's notes, and existing museum records.

The bibliographic information and digitization specifics were methodically arranged into tabular formats for easy access and understanding, and careful consideration was given to their design, featuring well-defined column headings, expected data formats, and controlled vocabularies for artifact types and geographical locations. The aim was to present the data in a more accessible manner, allowing effortless updates by curators and other relevant parties.

To ensure the utmost integrity of all gathered data, a crucial cross-validation process was put in place, involving the thorough examination and verification of the data by a specialized team of data

curators. In addition, this team carefully considered the utilization of Linked Open Data to shape the final data set, thereby aiming to enhance interoperability, machine-readability (David et al., 2023), and adherence to the already mentioned FAIR principles (Wilkinson et al., 2016). The careful transformation of the tabular data into Resource Description Framework (RDF) format was achieved as a result (Cyganiak et al., 2014). This was accomplished through meticulous processes, utilizing two distinct data models, rooted in the CIDOC Conceptual Reference Model (CIDOC CRM) (Doerr, 2003) and its extension, CRM Digital (CRMdig) (Doerr and Theodoridou, 2011). The standardisation of data semantics and its interoperability were facilitated by this transformation. To effectively track the provenance of data and understand its evolution over time, an elaborate provenance model was implemented as well. This system, based on the OpenCitations Data Model (OCDM) (Daquino et al., 2020), captures data snapshots, including timestamps, the responsible agents, primary sources, and a link to the previous snapshot, providing a comprehensive historical record of the data's evolution. Moreover, in order to offer a user-friendly interface for data exploration and visualization, the team harnessed an online dashboarding system, MELODY (<https://projects.dharc.unibo.it/melody/>). This solution empowers users to perform queries on Linked Open Data sources using SPARQL and create compelling data stories, featuring a range of components such as charts, maps, and graphs (Daquino & Renda, 2023).

Further, in order to ensure the same openness of access and to facilitate the retrieval of this valuable information by external applications, all the metadata associated with the 3D models of the digitised objects have been carefully incorporated into the digital library records, thanks to the ATON framework used for this task.

Acquisition:

Early in the acquisition campaign, as the team navigated the intricacies of post-processing, the need to verify the positions of objects and their relation to curatorial narratives arose. Additionally, some items had to be returned to their respective owner institutions before the exhibition's closure, putting their documentation and acquisition at risk. In response to these challenges, a rudimentary mockup of the exhibition was created as a shared reference point during the creation of the Digital Twin. Due to time limitations, the decision was made to utilise 360 panoramas for a Virtual Tour (VT) as a practical solution.

VT, especially at 360 degrees, have become essential tools for many domains (Pescarin et. al, 2023), such as education, tourism and commerce, as they are versatile vehicles for communicating diverse information enriched with multimedia. With the advent of immersive VR headsets, they

additionally offer users an unparalleled sense of presence, fostering engaging experiences. Furthermore, in the Cultural Heritage's sphere, their prevalence has gained greater importance, especially in response to the challenges posed by the COVID-19 pandemic (Amir et al., 2021; Wu, 2022).

In the pursuit of creating a VT for the Aldrovandi exhibition, 360-degree spherical or equirectangular images (Fig. 27) were utilized with the aid of an Insta360 ONE X2 camera, specifically designed for panoramic image and video capture. Ultra-high resolution images were unnecessary due to the camera's capabilities and its calibrated positioning were enough to mimic the visitor's perspective. Also, real-time review and adjustments were facilitated by a tablet connected to the camera through Wi-Fi, streamlining the process and minimizing the likelihood of errors. The resulting images were meticulously edited and exported at the highest resolution of 6080 x 3040 pixels. The individual panoramas were subsequently uploaded to the shared cloud repository as additional and valuable documentation material.



Figure 27, Examples of spherical or equirectangular images from the Room 3 of the exhibition, source: Balzani et al., 2023.

Lastly, the complex task of interconnecting these shots was executed using Pano2VR (<https://ggnome.com/pano2vr/>). This versatile software application converted the acquired panoramic images into web-compatible formats (HTML5/CSS3) that enable them to be experienced across multiple platforms (Cao, 2022). By importing them into this chosen software, a connected path was designed to mirror the physical exhibition's original route. The resulting VT was further enriched with additional interactive elements, including informative pop-ups, photographic hotspots, directional audio, and video segments. Moreover, all the visual aesthetics related to the

User Interface (UI) were customizable through the use of CSS thanks to the Skin Editor tool (Fig. 28).



Figure 28, Two different UI of the virtual tour navigation mode, designed by the Skin Editor tool, source: Balzani et al., 2023.

This interim solution of creating VT of the Aldrovandi exhibition using 360-degree panoramas provides an intriguing preview of a possible intermediate preservation goal outcome. While the ultimate objective of this initiative remains the development of a comprehensive Digital Twin, these images have proven to be valuable in their own right as they offer a tangible sense of the exhibition's original setup, content, and the narrative flow.

Regarding the actual acquisition phase, the exhibition featured a total of 301 items, primarily sourced from Palazzo Poggi's permanent collection. Additionally, a smaller portion of the objects was generously lent by various cultural institutions, including:

- The University Library of Bologna (BUB);
- The Library of the Department of Biological, Geological, and Environmental Sciences (Bertoloni Historical Fund)
- The Library of Mathematics, Physics, and Computer Science (Physics Section - "Guido Horn D'Arturo" Historical Library);
- The Department of Biomedical and Neuromotor Sciences;
- The Medieval City Museum, the Archaeological City Museum;
- The State Archives of the city of Bologna;
- The Carrara Academy of Bergamo;
- The Museum of Civilisations
- The Spada Gallery of the city of Rome;
- The Academy of Physiocritics of Siena;
- The Natural History Museum of Verona.

The work spanned three months, starting from the end of March 2023 and concluding at the end of June 2023, when the exhibition was already ongoing, which proved to bound the overall work to specific time constraints and add complexity to the acquisition process. Foremost, access was primarily restricted to Mondays when the museum was closed to the public. During these days, the teams operated from 9:00 to 16:00 for nine days, with an additional four days granted when one of the rooms was closed for reorganization, leading to a total of 91 hours. Secondly, as just briefly mentioned, some of the objects were on loan from other institutions and needed to be returned before the exhibition's end. Due to these challenges, coordination among all the groups was crucial.

Space constraints in the museum posed additional complications too, given the numerous display cases, technical equipment, and a limited number of electrical sockets and supports. In response, temporary stations with camping tables were used to minimize the distance from the original display space. Plus, on Mondays, two marble tables in other museum rooms were available, offering an ideal setting for acquiring some objects.

Besides time and space constraints, as expected, there were also material-related challenges. All the items exhibited, in fact, remarkable diversity in terms of geometric shapes and surface characteristics, adding layers of complexity to the overall digitization. The array of materials encompassed manuscripts, printed volumes, ancient maps, woodcuts, technical and scientific instruments, statues, specimens, and archaeological finds. Room 5 was the most challenging one to address as it hosted a vast and varied collection of natural artifacts, including large marine turtle shells, amphibian and cartilaginous fish specimens, geological samples, minerals, fossils, and microfossils, further complicating the process.

Altogether the exhibits consisted of 104 specimens, 27 printed volumes, 17 manuscripts, 5 nautical charts and maps, 1 diorama, 7 herbariums, 21 models, 7 woodcuts, 3 paintings, 6 painted ceilings, 11 casts, 2 medals, 4 scientific instruments, and over 30 other objects, encompassing archaeological remains. Multimedia assets were also present, featuring 9 videos, 2 prints, and 27 panels with graphics.

Room n. (n. of objects)	Types of objects (n. of objects)
1 (30)	Video (2), Specimen (8), Printed volume (6), Nautical chart (3), Print (1), Diorama (1), Herbarium (1), Manuscript (1), Painting (1), Rooms/Painted ceilings (1), Panels with graphics (5)
2 (39)	Herbarium (6), Printed volume (4), Manuscript table (4), Specimen (4), Model (3), Manuscript volume (2), Map (2), Paintings (1), Vase (1), Rooms/Painted ceilings (1), Video (1), Panels with graphics (10)
3 (20)	Woodcut (7), Printed volume (5), Video (2), Manuscript table (1), Rooms/Painted ceilings (1), Panels with graphics (4)
4 (13)	Video (2), Knife handle (2), Printed volume (2), Mask (1), Pendant (1), Rooms/Painted ceilings (1), Panels with graphics (4)
5 (146)	Specimen (79), Artifact (23), Cast (9), Gemstone (9), Manuscript volume (8), Printed volume (5), Medal (2), Statue (2), Video (2), Manuscript table (1), Necklace (1), Rattle (1), Lamp (1), Axe (1), Print (1), Rooms/Painted ceilings (1)
6 (53)	Model (18), Specimen (13), Printed volume (5), Cast (2), Print (1), Illuminated manuscript (1), Manuscript table (1), Painting (1), Microscope (1), Compass (1), Bottle (1), Electrostatic machine (1), Discharge arc (1), Technical instrument (1), Rooms/Painted ceilings (1), Panels with graphics (4)

Table 5, The rooms, types and number of objects in the “The Other Renaissance” exhibition, source: Balzani et al, 2023.

To tackle this diversity, the team’s strategy relied on established remote-sensing technologies commonly employed in Cultural Heritage preservation, such as 3D structured light projection scanning (SLS) and photogrammetry, each selected based on the properties and constraints of the objects. Structured light projection scanners, while costly, allowed for rapid and accurate data acquisition, while photogrammetry, with its adaptability and high-resolution image capture, proved effective for capturing irregularly shaped items, lowering costs and reducing acquisition time.

When employing structured light projection scanning (SLS) and photogrammetry techniques, it became evident that non-Lambertian materials, such as those with reflective surfaces or those that change color with viewing angles, could significantly complicate the process. To mitigate this, strategies like cross-polarization and the use of light boxes were implemented to reduce the effects of specular reflections and capture more consistent data. In cases where object mobility was restricted or there were glass cases, fabric screens and precise setup adjustments came to the rescue.

Materials like clear transparent or translucent substances and polished metals presented a different set of complexities, requiring individualized solutions.

Objects with intricate details, such as hairs, fur, fibres, and delicate structures, were approached with care and, if necessary, received special treatment during the modeling phase. Furthermore, objects with complex geometries and tight time constraints, like the Basilisk (Fig. 29), demanded quick yet meticulous acquisition procedures. In such instances, precise camera settings and an intermediate light intensity were employed to achieve high-quality results within a limited time frame. Overall, a combination of innovative techniques, expert knowledge, and meticulous planning allowed the project to overcome these material-related complexities and successfully capture the objects from the exhibition.



Figure 29, Original photo and 3D model of the Basilisk, source: Balzani et al., 2023.

Overall, given the limitations and challenges presented (mainly time, space, and material-related), a combination of innovative techniques, expert knowledge, and meticulous planning played a pivotal role as they allowed the project to successfully achieve their objectives. This careful selection enabled research teams to progress efficiently, while also gaining valuable insights and helping address these commonly encountered challenges.

N.	Risk	Solution(s)
1	Acquisition of non-Lambertian materials	<ul style="list-style-type: none"> • Cross Polarization: creating a set-up with light sources screened with polarized filters; • Minimize effect on the reconstruction process by lowering the illuminance of light source using white lightboxes, substituting the whole environment with his hard light sources with a self-illuminated white box where the light intensity is almost evenly spread on all the surface.
2	Impossibility to move some objects and to open glass cases	Interposing white fabric screens between light sources and object, with all ambient light shut down and light sources positioned on opposite sides of showcase, high above its top surface, with an inclination of 45° (emitted light hit the fabric sheets and generated a lightbox effect) add black fabric curtains placed behind the cameras to avoid reflections on the glass (cameras remotely controlled).
3	Materials with no intrinsic proper colour (clear transparent or translucent materials and polished metals)	<ul style="list-style-type: none"> • Glass: techniques used by Karami et al. (2022); • Translucent: cross-polarization techniques (Angheluta and Radvan, 2020); • Computer Graphics modelling: if geometry is simple enough, measuring with simple tools like a metre and callipre and then direct modelling in 3D.
4	Presence of physical colours	Cross Polarization and avoidance of too different acquisition positions.
5	Complexity in size and details (i.e. hairs, fur, fibres, frayed edges, thorns, spikes, and teeth)	<ul style="list-style-type: none"> • Computer Graphics modelling: direct intervention on the model to optimize details; • For sharp objects with a small diameter but a considerable height, segment the data by slicing portions horizontally.
6	Time constraints versus object complexity	<ul style="list-style-type: none"> • Luhmann et al. (2020) formula; • High overlap of acquired photos; • Lightbox set with intermediate intensity (in case of reflections); • Microstructural details acquired setting larger aperture (Nicolae et al., 2014).

Table 6, The risks and related solutions adopted in the acquisition and processing of the exhibition objects, source: Balzani et al. 2023.

The Rooms:

After actively participating in the initial stages of object acquisition, especially in the first two rooms, I then moved to carry out a thorough evaluation of the exhibition's floor plan. This change marked a shift from curating the physical items to embarking on the intricate process of creating their digital counterparts within the virtual domains of the exhibition.

The exhibition was ensconced within the historic confines of Palazzo Poggi, an architectural gem which dates back to the 16th century and was originally built as the residence of the Poggi family. In 1711, the palazzo underwent a significant change in its purpose and became home to the Institute of Science and the Arts (Rosati, 2020). Following the Napoleonic reforms, the University was relocated to this revered institution in subsequent epochs, leading to the dispersion of the original historical collections across other specialized university and city museums. A significant turning point occurred towards the end of the 20th century, when an extensive cultural restoration effort paved the way for reuniting the whole Aldrovandi collection within these historic and original walls (Latini, 2005).

In achieving the primary aim of the CHANGES initiative, beside the faithful digital reconstruction of the objects themselves, it was equally imperative to replicate their surroundings, encompassing the exhibition's spatial layout, architectural elements, and visual context, right down to the panels and displays, aiming at the craft of a more immersive and comprehensible digital exhibition environment for the users.

Within this historic palace, intricate frescoes and paintings adorned walls and ceilings dating back centuries. At this unique juncture, our endeavor to reproduce the museum spaces necessitated a delicate balancing act. The main focus was to maintain the cultural and artistic significance of Palazzo Poggi's architectural features, while simultaneously creating an optimized final model. This called for our careful alignment of both the geometry and textures, as ensuring real-time and online accessibility is a crucial objective of this overall initiative.

We collectively decided to devise a pragmatic approach to address this challenge, opting to use photogrammetry only to capture the painted decorations of the ceiling and upper side of the wall. In parallel, I begin to model the six rooms' overall architecture, displays, and museum cases in Blender (<https://www.blender.org/>), starting from architectural plans, blueprints, and curatorial documentation provided by the SMA's staff.

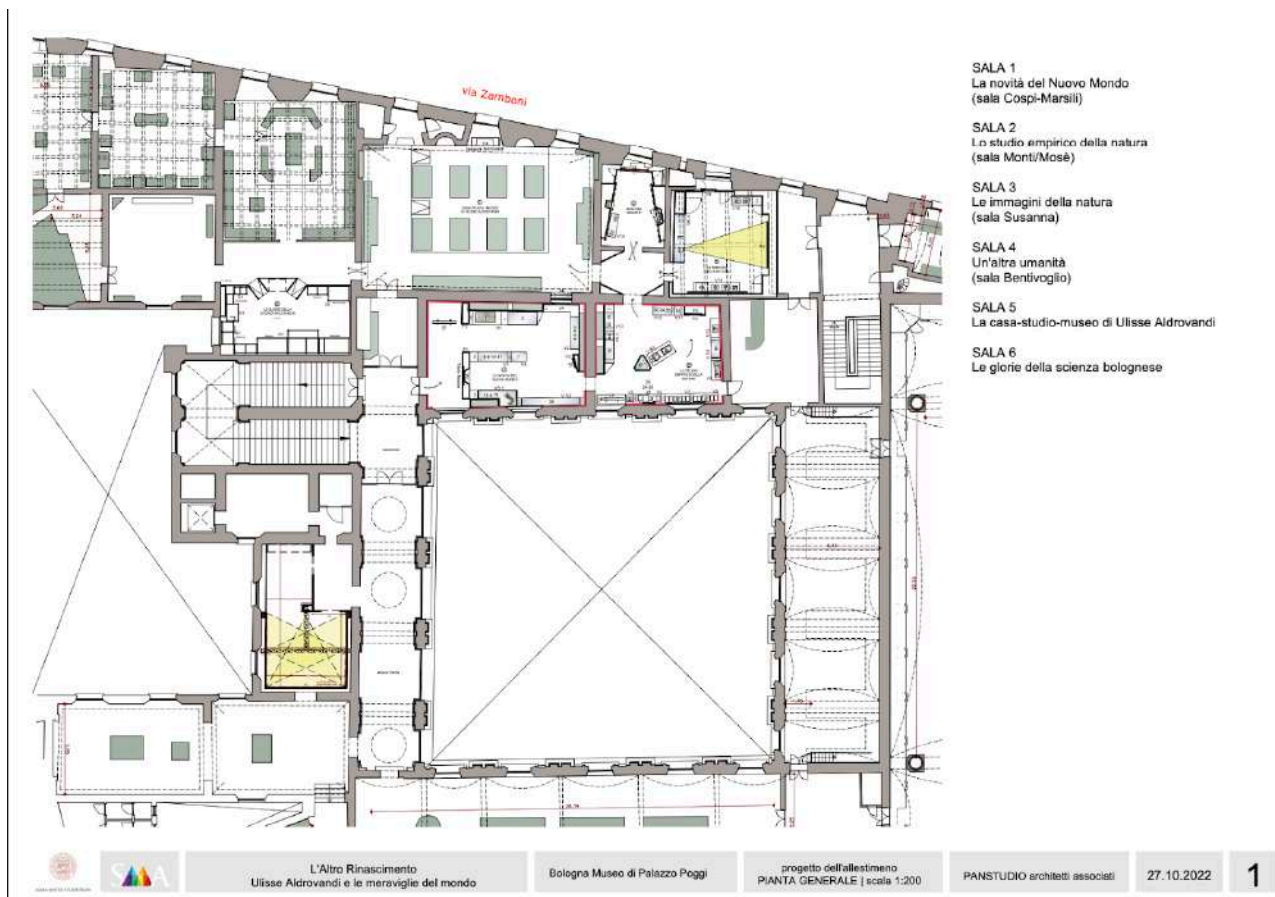


Figure 30, Exhibition's floor plan, source: SMA.

SALA 1

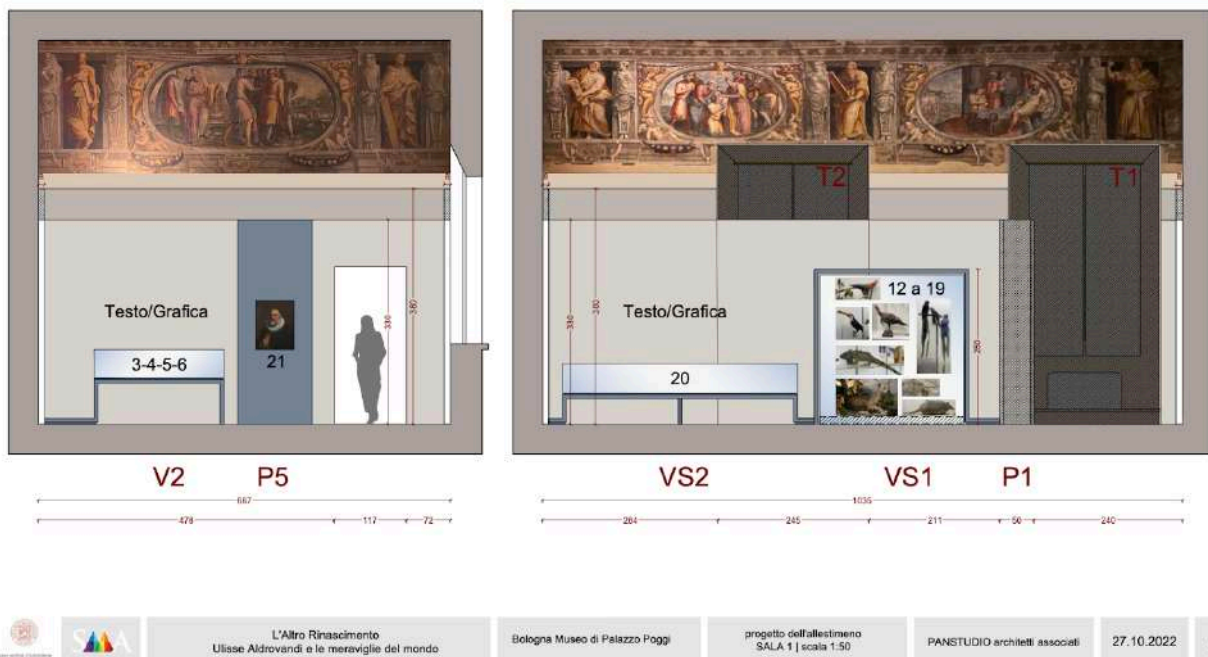


Figure 31, Exhibition's set up design, Room 1, source: SMA.

As the photogrammetric acquisition progressed, I was able to capture the beauty of the frescoes and friezes situated at great heights from a low angle thanks with a fixed camera on a tripod. The ornately decorated beams, a unique characteristic arising from the ceiling's distinct structural composition, were given particular attention in this phase. After acquiring all the necessary images, they went through a comprehensive processing using 3DF Zephyr (<https://www.3dflow.net/3df-zephyr-photogrammetry-software/>), a Structure from Motion (SfM) software, adhering to up-to-date data processing practices. Any hidden areas or gaps were then meticulously addressed through interventions in Computer Graphics modelling, which resulted in the final 3D model of the ceiling.

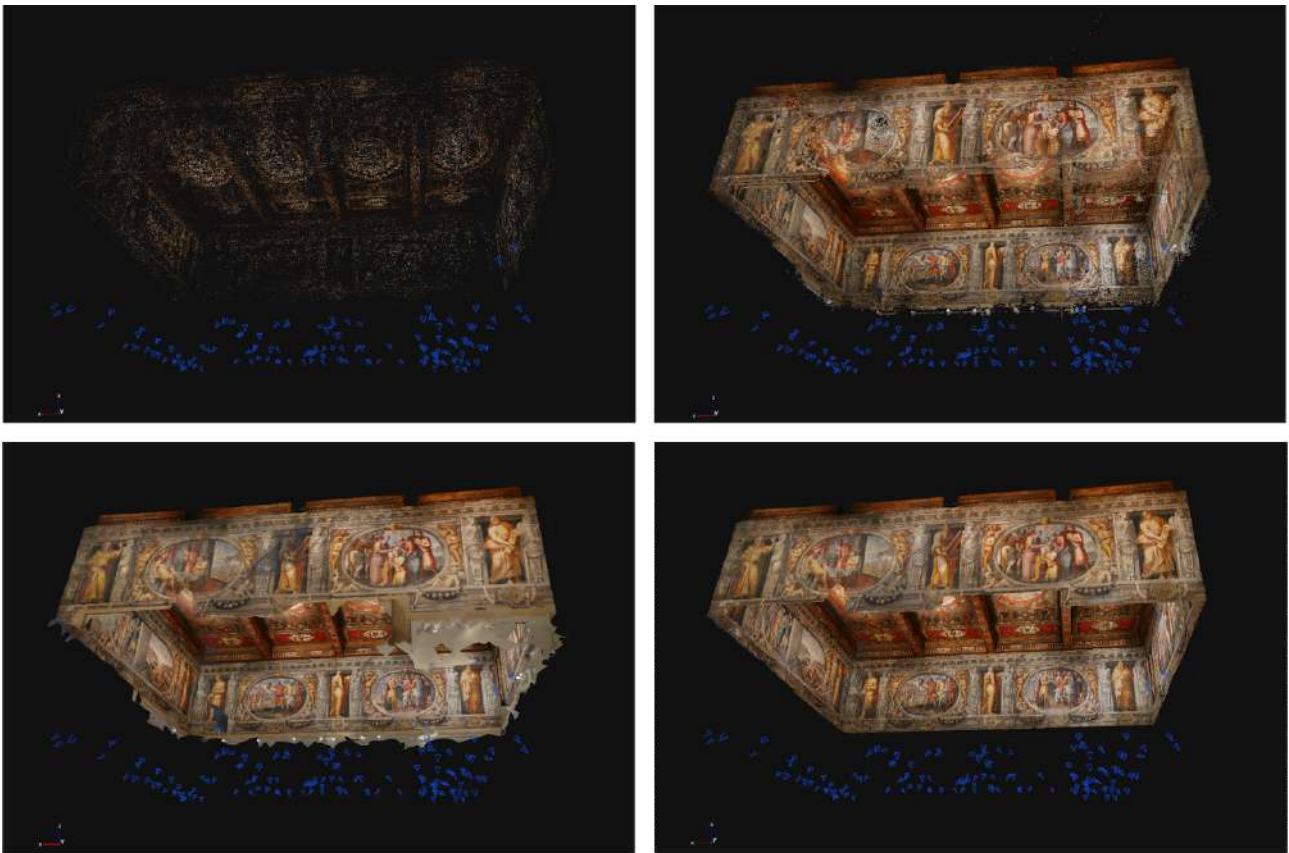


Figure 32, From left to right: sparse cloud, dense cloud, mesh and textured mesh of Room 1' ceiling in 3DF Zephyr.

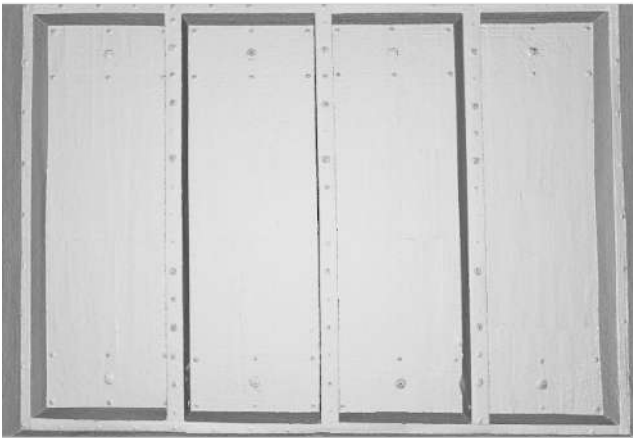


Figure 33, 3D model with and without texture of Room 1's ceiling in Blender and a close up angle .

To ensure a clear separation between the two acquisition modes, a semantic layer that differentiates between the sections of models obtained through photogrammetry and those modelled in computer graphics was implemented. This adhered to the guidance provided by the London Charter (<https://londoncharter.org/>) for a methodical and structured recording of our digital reconstruction process.

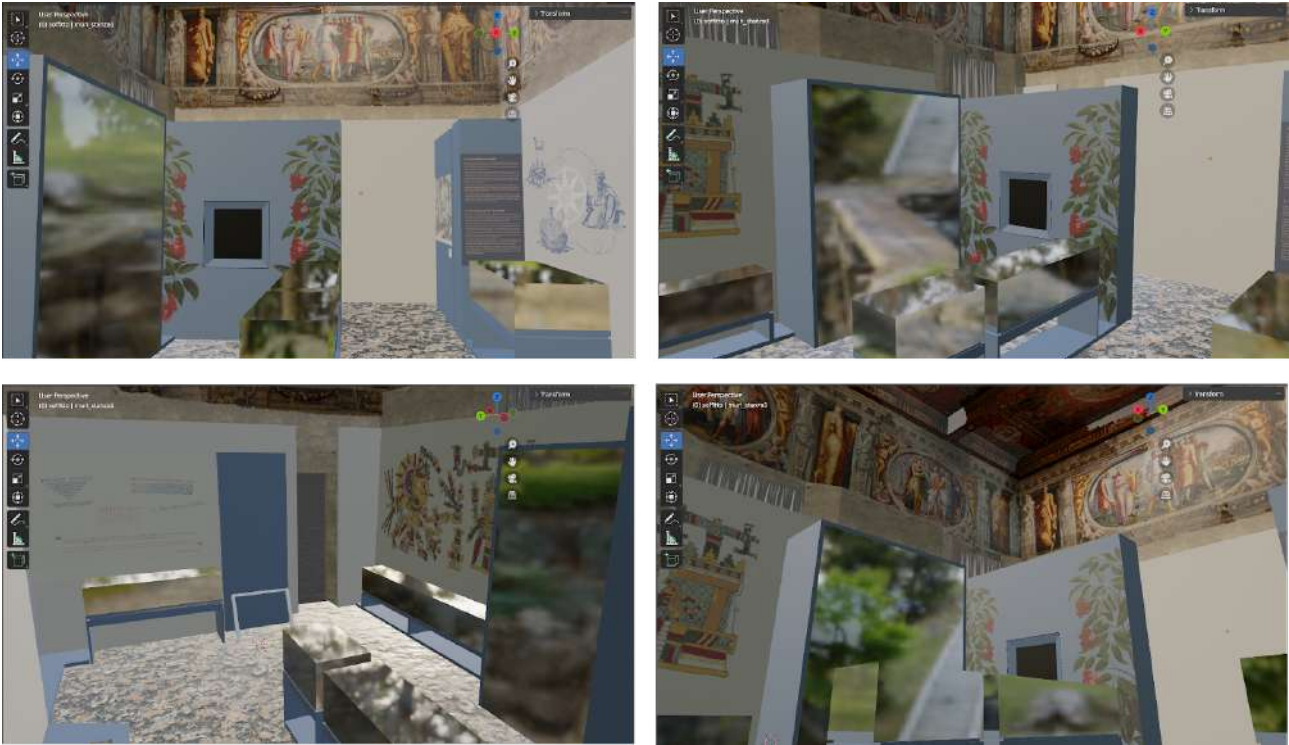


Figure 34, 3D reconstruction of Room 1 in Blender with no exhibits.

After the documentation and acquisition phase in the process towards achieving the final Digital Twin, the curation phase of all previously gathered and created digital assets became crucial. This stage involved several key steps, such as modeling, optimization, and publishing in ATON.

Firstly, as already seen, all the 3D models have been generated either from photogrammetry or scanner post-processing. These initial models, often referred to as “level 0”, might present topological issues, such as holes, non-manifold edges, and overlapping faces due to survey conditions or the nature of the items. For instance, delicate items, like manuscripts, might only have data available for their front and side views. In order to address these kinds of topology irregularities, a combination of Instant Meshes and editing and sculpting tools in Blender were employed to address topological problems and create regular topology. The overall end goal was to produce models with a high level of precision and photorealism, the so-called “level 1”.

For additional optimization, a “level 2” model was generated by making again use of Instant Mesh. This brought to the creation of a low-polygon model while also preserving the original shape and boundaries, resulting in a pure quad mesh. UV coordinates were introduced for texture mapping, and meticulous manual organization of the UV space was performed to prevent overlaps, prioritizing UV islands related to the exposed parts of items, making the best use of available UV space.

Once the models have been refined and optimized, they were exported in glTF format, which is well-suited for Web3D applications and facilitates navigation and sharing, and then upload on ATON, the open-source system developed by CNR-ISPC already introduced in the State of The Art chapter (2.2.2.) and chosen for this specific undertaking.

The ATON Framework is built on strong web standards and open-source technologies like Three.js and Node.js, and offers scalability and adaptability enabling the creation of cross-device Web3D/WebXR applications tailored for the Cultural Heritage domain, multi-user experiences such as virtual forums, educational tools, and multiplayer 3D gaming. Also, within ATON, objects can be organized in 3D scenes, which can reference also multiple items - extremely suitable for creating 3D galleries in online virtual museums. Each scene is assigned a unique scene ID within the framework, allowing web apps to access and operate with specific published scenes. The content organization and management are made user-friendly through the Shu back-end system where the uploading process of our models actually took place.

With the foundation in place, as seen in the preceding sections, it is now time to move to the next phase of this initiative: the exhibition curation in digital form and subsequent publishing.

4.2. Towards the Digital Twin

This endeavor has been marked by a dedication to important principles, including innovation, interactivity, semantic richness, and collaboration from the very outset. These factors will ultimately culminate in the final Aldrovandi exhibition Digital Twin, where the digital preservation strategy underpin both the documentation and further improvements regarding its representation, accessibility, and reusability in the scientific community and for the general public –pivotal targets of this project.

This will enable continued virtual accessibility of this major cultural effort. Moreover, the Digital Twin has the capability to go beyond the static observation of physical objects. Users can interact with the digital representations of objects by zooming, rotating, and exploring them in more detail. This enhanced interactivity offers a dynamic and engaging experience.

The culmination of this project will thus grant continued and enriched virtual access to this significant and complex cultural event and endeavor, giving users the ability to explore the past exhibition and follow the original curatorial narrative among the masterpieces on display within the rooms of Palazzo Poggi from the comfort of their own homes via a web browser and their own devices. The Digital Twin, transcending physical constraints and static observations of objects, will additionally give the unique opportunity users to interact with it on a much more advanced level of immersion and interactivity, no longer bound by the confines of glass display cases or crowds. Instead, they will engage with the digital representations of artifacts by zooming, rotating, and exploring them in more detail.

Furthermore, the integration of Linked Open Data, Knowledge Graphs, Semantic Web and 3D technologies unlocks a new level of relations, which will be implemented by leveraging ATON's specific features, including semantic annotation. These connections extend beyond the exhibition, allowing for a broader exploration and contextualization of culture and history.

To date, the project has chosen to approach the 3D models of the exhibits by categorizing them into three distinct groups: artifacts, videos and manuscripts. This division is driven by the unique visualization and enrichment requirements for each type of exhibit. All categories will include their 3D model (or player in the case of videos) and essential metadata, ensuring that users have access to relevant information about each exhibit and a dynamic and immersive viewing experience. In addition, these categories will be enriched with carefully selected external resources, offering users additional avenues for further explorations. The manuscripts' category, on the other hand, benefits from a fruitful collaboration with the Library of the University of Bologna, which has already digitized and published all the manuscripts on display. The resulting interface for each exhibit will provide users with the desired enhanced experience, additionally contributing to the overall interaction and understanding of the past exhibition.

In summary, the ongoing evolution of this project will place a strong emphasis on curating the user experience and enriching content. As a matter of fact, enhancing the exhibition with additional information also serves a valuable resource for our second primary target user, the scientific

community of researchers and experts, who seek to explore, discover, make use, and possibly build upon this supplementary repository of knowledge (Fiorini et al., 2022). Furthermore, this digital transformation opens the door to unprecedented narrative opportunities where users transition from passive observers to active contributors (i.e., through annotations on digital objects). This collaborative and participatory experience will foster a sense of community and engagement, allowing users to share their unique perspectives and interpretations, thereby strengthening social cohesion (Pescarin et al., 2023a).

To conclude, it is crucial to emphasize that the main goals of digital exhibition curation have been set. Nevertheless, the project is still ongoing, and the new virtual experience is currently in its prototype status. As the project continues to evolve, these objectives may be refined and extended to shape the immersive and enriching experience the team aspire to deliver for all users. With each progression, new challenges may emerge, sparking the need for innovative solutions to ensure the initiative's ultimate success.

5 CONCLUSIONS

The research set by this thesis originated from the dual aspirations of investigating the underexplored realm of preserving temporary exhibitions as well as finding effective solutions to address this complex matter. It commenced with an in-depth examination of the state of the art of existing preservation techniques, noteworthy projects, and technologies relevant to this ultimate objective (Chapter 2). To enrich this inquiry, a series of additional data collection activities were conducted, including questionnaires with experts in the field and additional one-on-one interviews with those deeply involved in key initiatives analyzed, all shedding light on critical lessons, challenges, and lingering open issues.

Building upon these elements, a conceptual framework was designed (Chapter 3) to tackle the intricate task of preserving temporary exhibitions in the digital era. Unlike one-size-fits-all solutions, this approach aims to offer a flexible and abstract methodology that institutions can customize to their unique objectives, resources, and capabilities. It proposes three different levels of preservation goals, with a thorough examination of the possible challenges within each step of the way.

Moreover, the framework introduces a novel temporal understanding of temporary exhibitions. By acknowledging the often-neglected dimension of time within their lifecycle, this new perspective enables an improved alignment of exhibitions with the phases of their digital preservation process. Integrating preservation goals and phases into the exhibition's planning, creation, closure, and beyond, in addition, equips entities responsible for such tasks with clearer guidance and tools to navigate these operations, promoting a proactive strategy rather than a reactive one.

In order to start evaluating the therein conclusions drawn, I have included in this inquiry the discussion a case study, the Aldrovandi exhibition's preservation project (Chapter 4), I personally participated in this year. This served as a focal point in this dissertation, representing a practical application of the developed framework. It scrutinizes the complexities encountered in preserving and translating this exhibition into the digital domain, detailing the initiative's stages and offering a comprehensive overview of insights gained through personal involvement and the collective efforts of the team thus far.

The main takeaways emphasise the challenges in pursuing such endeavors, particularly as the exhibition was still ongoing, and the numerous material-related hurdles encountered when creating

digital assets specifically of cultural heritage objectives. Several open issues are currently under examination, underscoring the necessity for additional evaluation and inquiry. Furthermore, the final chapter also previews the forthcoming stages and the sustained evolution of the Aldrovandi's initiative.

In conclusion, this thesis presents a comprehensive exploration of preserving temporary exhibitions in the digital era and propose an adaptable framework to guide institutions in these kinds of endeavors. It is hoped that this project, alongside the wider field of digital preservation, will continuously refine and expand the strategies and methodologies here presented.

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