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THE IMPACT OF VISUAL TWINS ON THE PRESERVATION OF ARCHITECTURAL HERITAGE: THE EXAMPLE OF CASA BATLLÓ

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Abstract

Casa Batlló, Antoni Gaudí's architectural masterpiece and UNESCO World Heritage Site, has unique conservation challenges due to its multi-material structure and organic forms. In response, visual twin solutions have emerged as an advanced tool for heritage science, based on precise documentation and an innovative virtual environment. This article examines how these technologies support both heritage conservation and visitor engagement. The research presented here demonstrates the diversity of strategies used to preserve and explore Casa Batlló's heritage. It describes Casa Batlló's recent renovation, highlighting the results of combining traditional craftsmanship with digital research, which ultimately revealed a new perspective on Gaudí's original design. Furthermore, data collection and the creation of a visual twin enable innovative visitor experiences, such as augmented reality tours, immersive installations, and large-scale projection mapping. Casa Batlló demonstrates a complex, integrated approach in which digital innovation complements traditional methods of protecting and revitalizing cultural heritage for future generations.

Keywords*: Visual Twins; Architectural Heritage; Protection; Conservation*

Introduction

The preservation of architectural heritage increasingly relies on the integration of advanced digital technologies. This enables accurate documentation, conservation, and even innovative forms of public engagement [1]. Moreover, it supports innovative public engagement. This is particularly significant in the case of complex, multi-material monuments such as Casa Batlló in Barcelona. It is a well-known Antoni Gaudí masterpiece and a UNESCO World Heritage site. Casa Batlló's organic forms, mosaic details, and innovative structural solutions make it a valuable object but also a significant conservation challenge due to the diversity of materials and the complexity of its components (Fig. 1).

Casa Batlló illustrates how large-scale digitization and the creation of digital archives can contribute to heritage preservation. These collected resources enable data-driven conservation strategies. Moreover, these technologies enable new forms of immersive visitor experiences through augmented reality applications that reveal Gaudí's creative process and facilitate much more engagement. This study explores the role of integrated digital and visual datasets at Casa Batlló as instruments for architectural heritage conservation and innovative interpretation. It examines the latest restoration and diversity of methodologies used. Impact of real-time visitor

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flow monitoring, the contribution of artificial intelligence, and innovative immersive technologies for accessibility and heritage protection. By detailing these aspects, the study highlights a holistic model for sustainable heritage management, combining scientific investigation with digital innovation.

Fig. 1. Casa Batlló's organic forms

Experimental part

Materials

Casa Batlló is a complex structure, with numerous unique details in both the facade and interior. The exceptional finishes and intricate connections require precise conservation techniques. Visual archival materials were collected specifically for Casa Batlló. A rich collection of data resources was gathered, serving both for scientific heritage conservation and for creating innovative forms of interaction with visitors. The materials encompass a wide range of sources: high-resolution 3D scans of the facade and interior spaces, digital archives of drawings, original Gaudí manuscripts, photographs, scholarly publications, and video recordings related to architects' visions and works [2].

This digital repository, already containing millions of documents and images, has grown into one of the world's most comprehensive heritage libraries [2]. The digitization process involves the collaborations between specialized archivists, conservation scientists, historians, and a network of volunteers. They all contribute to cataloging, scanning, and indexing fragile historic artifacts, transferring them from a physical medium to a durable, searchable digital form [3]. Artificial intelligence algorithms, supporting the search for distributed visual resources, also proved to be important in this process. This archive serves as a foundation for research and innovative initiatives, providing raw data for analyses and a rich historical context for strategic decisions.

Methods

Scope of Restoration

The latest renovation project took place between 2018 and 2025. Casa Batlló featured the results of its conservation efforts in a series of videos describing the solutions used. Comprehensive renovations were carried out based on the collected data. Casa Batlló boasts a

well-known front facade, but previously less important areas were also addressed. The main changes concerned the neglected courtyard and rear facade. Instead of simple repairs, highly complex steps were undertaken. Visual archives were searched, and traditional craftsmen hand-assembled the details. Many discoveries emerged, including the discovery of original colors that no one expected. The restoration of Casa Batlló was carried out in accordance with UNESCO and ICOMOS regulations. The goal was to capture the master's original intentions [4].

Before physical work began, extensive research and material analysis were conducted. The first major step was to identify the original colors. To determine the original colors of various architectural elements, primary source materials were sought. Excavations were also made for comparison. Some discoveries challenged earlier assumptions. Wrought iron elements such as grilles and balconies were long considered black, but research revealed that the original color was white. The plaster on the facade and patio, commonly considered yellowish, was also identified as dark gray. Window frames, often considered white, were originally green. These discoveries revealed a surprising contrast, radically altering the perceived visual harmony and deepening our understanding of Gaudí's original design [5].

Restoring the mosaic, made from fragments of ceramic and glass, known as *trencadís*, was a multi-step process. The method involved scanning all components, supported by the analysis of historical photographs. This enabled the separation of the originals from later additions. Each fragment was classified, its state of wear assessed, and the technique chosen based on the extent of the damage. Damaged elements were restored in situ on the facade or in specialized workshops. Missing fragments were reconstructed with attention to color differences, distinguishing between the methods used with ceramics, glass, and other materials [6].

Similarly, the wrought iron, balustrades, flower stands, balconies, and similar elements were entrusted to master craftsmen. Inauthentic or damaged sections were removed, replicating new ones in the original style. This work requires skills and many months of precise handwork. The work involved included detail drawing, profiling and polishing, and the faithful reproduction of minute details [7].

Wooden elements are found both inside and outside the building. The bay windows proved to be the greatest challenge. They bring light and additional air into the interior. Many of the window frames have been replaced over the years. Only two of these elements remain in very good condition; the rest require restoration. Because two elements were preserved in very good condition, they served as a model. Based on this, under the guidance of carpenter Josef Bartoli, the original wood style of the facade was restored, while a detailed reconstruction of the missing structures of the interior gallery was also carried out. This was a very labor-intensive task, undertaken by an entire team of carpenters. This often requires hand-working with traditional tools to extract the complex form and preserve its authenticity [8].

Renovation of the small metal elements such as door handles and hinges was also very important in terms of integrity with the original vision. Antoni Gaudi designed these elements individually for each structure, adhering to ergonomic principles but also with exceptional aesthetics and attention to detail. Elements requiring intervention were carefully photographed, disassembled, and described. Then, old coatings were removed, and cracks were welded or replaced with new ones. This was followed by sanding, refining, and, optionally, finishing with varnish or metallic coating. The final step was precise assembly to ensure everything functioned flawlessly. Therefore, the renovation projects were carried out using traditional techniques to best capture the authenticity of the details [9]. The restoration project based on collected data has not

only recovered the building's authenticity but also led to surprising discoveries, including original colors and previously unseen structures [10].

Data Collection and Digital Archiving

High-resolution laser scanning and photogrammetry were used during the restoration. These methods focused on reproducing the facade, interiors, and details of Casa Batlló. These techniques produce precise 3D point clouds and modeled textures, resulting in extremely accurate documentation. Such methods have already proven to be effective in architectural heritage conservation projects. Given the organic and complex shapes of Casa Batlló, these techniques proved essential [11].

To complement the 3D geometric data, extensive digitization of bibliographic and visual archive resources was undertaken. Original historical drawings, construction documents, conservation records, and photographs were scanned. A workflow was used to avoid damaging delicate materials. This multi-format dataset was then systematically organized into a digital library. Integrating such diverse datasets improves the interrelationship between physical building conditions and historical documentation. The next step was the integration of real-time data from environmental sensors, collected via a distributed network using Beacon Technology, to track the location of visitors and staff in real time. Sensor data is streamed and synchronized to dynamically reflect the current status [12].

Innovative Visitor Experience via Digital and Visual Twin

Barcelona is focusing on applications such as Digital and Visual Twin in its urban strategy. These solutions are designed to enable better urban planning by taking into account large amounts of real-time data. Without the help of appropriate artificial intelligence algorithms, it would be impossible to analyze such large data sets. The primary goal is to ensure sustainable management of city resources through scenario simulation. It also aims to enable interactive engagement with the city's heritage and infrastructure and improve the tourist experience. Barcelona is a city visited by a large number of tourists. Proper management is crucial for the city's sustainable development and the provision of appropriate infrastructure for residents. An example that clearly illustrates the potential of such solutions was the study of whether Barcelona is a 15-minute city. The analyses covered basic functions that should be accessible within a 15-minute walk. Such analyses provide the opportunity to understand and plan the city's development in many areas [13].

Within the broader context of the initiatives undertaken in Barcelona, the Visual Twin concept at Casa Batló reflects the trend of using technologies to protect and present architectural heritage in innovative ways. It receives a huge number of visitors each year. This poses numerous challenges in terms of appropriate heritage preservation while maintaining its accessibility for tourists. This building has been a significant landmark in Barcelona for many years. From 2013, Casa Batló began introducing interactive elements for visitors. In subsequent years, the first mappings on the building's facade were also introduced. The first projections on the facade were revolutionary. In 2022, digital artist Refik Anadol created “Living Architecture” (Fig. 2), an innovative work of art that changes in real time through data collected from the environment and processed by artificial intelligence algorithms. The corresponding dynamic NFT was auctioned at Christie’s, symbolizing a fusion of heritage with avant-garde digital art [14].

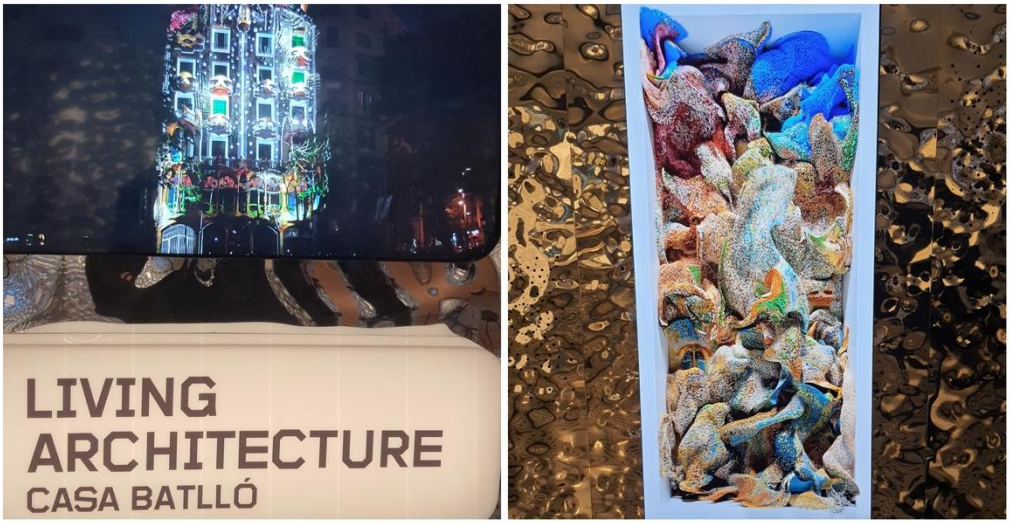

Fig. 2 Living Architecture, Refik Anadol digital projection

Casa Batlló continually refines its interactive heritage experiences, aligning with Barcelona's digital transformation. These efforts are based on an extensive digital archive, also created for conservation purposes. The latest project, "Gaudí Dreams," is an installation at Casa Batlló that symbolically immerses visitors in Gaudí's mind. It is a mesmerizing journey through digital experiences (Fig. 3).

Fig. 3. Gaudi Deams, artwork by Anadol Refik

It also represents an innovative, multi-sensory reference to Gaudí's innovations. These innovative solutions, called the Casa Batlló 10D Experience, immerse visitors in the master's visionary world through sensory-enriched environments (Fig. 4).

Fig. 4. Casa Batlló 10D Experience, six-sided LED immersive space

The Casa Batlló 10D Experience features a range of activities. These include the Gaudi Dome, the Gaudi Cube, an interactive audio guide with augmented reality elements, and multi-sensory effects. Gaudi's Dome consists of over 1,000 screens and a modern sound system. The installation aims to show the world through the eyes of the young Gaudí. Natural landscapes and visualizations are displayed, revealing Gaudí's childhood inspirations and his connection to nature.

Gaudi's Cube is an immersive, hexagonal LED space in which dynamic visualizations are generated using artificial intelligence. Screens are located on the walls, floor, and ceiling. This solution is unique on a global scale. It is a narrative journey that brings Gaudí's architectural motifs and symbolism to life. The multi-sensory solutions utilize multiple senses. In addition to seeing dynamic images, visitors can feel the wind, feel vibrations in some rooms, and touch various structures. This is intended to create unique experiences for visitors.

To provide visitors with additional details and inspiration, augmented reality also plays a key role during the Casa Batlló tour (Fig. 5).

Fig. 5. Augmented reality solutions at Casa Batlló

Visitors using tablets can witness the transformation of the original 19th-century building into Gaudí's masterpiece. AR applications connect directly to 3D models. Visual twin archives

allow for the reconstruction of invisible layers within the building and Gaudí's innovative design solutions. Moreover, natural inspirations and symbols are also presented. Voice narrations provide additional historical and technical context, adaptable to user interaction and available in multiple languages. In the Noble Floor, which was a private residence, virtual reconstructions using augmented reality present life in the early 20th century and reveal the daily affairs of the residents. Here, visual effects also play an important role. The use of sound immerses visitors in these environments and the atmosphere of the early 20th century. The attic rooms focus on engineering by presenting interactive 3D models of Gaudí's ingenious structural systems.

Moreover, by using augmented reality in a typically crowded environment, tourists can admire all the elements more comfortably. This is a significant feature for Casa Batlo. Researchers point out many advantages of this solution in crowded interiors [15]. Unlike typical augmented reality systems, the one used in this facility does not require additional markers on surfaces. User positioning is solved without relying on image tracking. The number of people present does not affect the experience, as the environment is designed to avoid occlusions that often occur when multiple users are present (Fig. 6). Regarding multimedia content, static elements are optimized for real-time rendering on devices, allowing virtual objects to achieve a very high level of geometric detail [16], [17].

Fig. 6. The benefits of augmented reality during a tour with a large number of visitors

Dynamic multimedia content, rendered live on devices, is seamlessly blended with the static assets through an extended cube map technique, ensuring a smooth and visually coherent augmented experience [18], [19]. This solution effectively solves one of the typical problems associated with museums with crowded spaces. This technology can support and improve the selection and presentation of exhibits, making museum visits more personalized and comfortable [20].

Another solution based on the collected data is facade mapping. This activity aims to present a new perspective on architectural heritage sites and create a publicly accessible display. As part of these artistic programs, the building's facade becomes the screen for periodic projection mapping shows. The "Arborescent" exhibition by multimedia artist Quayola brought the facade to life using algorithmic tree-like formations. The visualizations depict natural growth and natural swaying, choreographed to an original soundtrack. This event attracted many viewers, merging

the organic inspiration behind Gaudí's design with contemporary digital media art, democratizing heritage by making it accessible outdoors to massive audiences [21].

Innovative visual solutions are used not only in the field of digital solutions but also through additional physical architectural elements. At the end of the tour, a modern architectural intervention was introduced. Japanese architect Kenzo Kuma redesigned the stairway [22]. The project was completed in 2021 and was not based directly on Gaudí's vision. The intervention reinterpreted the space but created a certain connection to the main patio. The most important element was the use of light in some aspects, analogous to Gaudí (Fig. 7). The interplay of light and shadow is a key design motif. Original aluminum curtains made of small elements were introduced. They reflect light, creating abstract shapes and an unusual atmosphere. This design emphasizes the central role of light in Casa Batló. Thus, the end of the tour shows visitors more contemporary solutions, but still with reference to the main theme of the Gaudí design.

Fig. 7. Redesigned staircase at the end of the visitor route

Technologies provide researchers and conservators with advanced tools for analyzing, predicting, and protecting architectural heritage. Together, the collected data and the Visual Twin can transform heritage into captivating, interactive narratives that transcend traditional museum presentations. Through these solutions, visitors to Casa Batló gain numerous opportunities to interact with Gaudí's legacy.

Results and discussion

The results achieved through the use of digital archiving, 3D scanning, real-time visitor flow monitoring, and immersive visitor experiences underscore the broad impact of these efforts. The creation of visual solutions at Casa Batlló has enabled advances in the management of the monument's conservation and increased value for visitors.

Digital Repository and Archival Integration

The digital repository and visual activities at Casa Batlló align with the most modern standards in the preservation and interpretation of architectural heritage. It houses a vast digital library dedicated to Antoni Gaudí. This extensive collection has grown over the years, drawing from historical archives, conservation documentation, and community contributions. Artificial intelligence algorithms were used to organize all the data into a coherent collection. Laser scanning and photogrammetry allowed the creation of precise, three-dimensional geometric models. These models form the foundation for the Visual Twin, providing a precise virtual environment.

This multi-layered digital collection also creates innovative paths for visitors. Detailed visual representations enable the use of augmented reality solutions, providing the opportunity for an interactive tour of Casa Batlló and providing a deeper insight into Gaudí's creative process. The abundance of information allows conservation activities to be very well planned and based on collected facts and documents. Current solutions are already very well developed and multifaceted in terms of the museum visitor experience. In the future, integrating more data in real time would also be a significant step in expanding the scope of Casa Batlló's digital and visual twin. The main applications of the collected visual materials are related to precise conservation based on researched historical data, innovative forms of heritage exploration, and appropriate tourist traffic management.

Immersive Visitor Experiences and Public Engagement

Casa Batlló's Visual Twin solutions have expanded the scope of heritage interpretation, providing visitors with rich, immersive experiences that deepen understanding and appreciation. The Casa Batlló 10D Experience combines AI-generated visualizations and multisensory environments. Interactive AR applications narrate Gaudí's creative inspiration and architectural mastery. These experiences go beyond traditional architectural heritage protection, employing digital environments to animate architectural features, thus transforming passive observation into active participation. The preservation and discovering of Casa Batlló's rich architectural and cultural heritage employ a multifaceted range of strategies that blend traditional conservation methods with digital technologies. A summary (Table 1) of the approaches implemented at Casa Batlló highlights the diversity of techniques and tools used to preserve the monument's authenticity while increasing public engagement and accessibility [24].

Table 1. Approaches implemented for preserving and discovering the heritage of Casa Batlló

Implemented approaches	Outcome
Traditional restoration	Combining historical research with traditional crafts
Digitization	Enriching the digital archive, preserving originals
10D Experience (Dome and Cube)	Multisensory visitors interaction
"Living Architecture" project	Immersive AI installation, heritage and digital art
AR Tours	Revealing details, educational outcome
A mobile application	Providing visitors with location-aware content
Indoor navigation and localization (Beacon system)	Precise directing guests
Platform for staff	Collecting and analyzing movement and behavior data
Projection Mappings	Outdoor art events connect heritage to global audiences

The activities and their outcomes illustrate the diversity of techniques employed, from traditional techniques to modern tools. It is certainly worth noting that technology plays a key role in shaping the activities undertaken at Casa Batló. However, a key feature is the harmonious integration of traditional techniques. Analyzing large amounts of data is also possible today through the use of artificial intelligence. Augmented reality tours and mobile applications provide dynamic, location-aware educational content.

Challenges and Future Perspectives

The first challenge was the ability to find and collect a vast amount of data. Searching for original sources is a long-term process. Determining the authenticity of the materials also poses challenges. Current artificial intelligence algorithms help structure this data, which is crucial in this entire process. In the case of such large databases, humans are unable to manually describe every photo, drawing, or other document. Furthermore, Casa Batlo analyzes live data, including

visitor numbers. This requires appropriate technical resources and personnel with expertise in managing large databases. Despite these challenges, this example demonstrates that managing a facility in this way offers many additional possibilities and seems to be a significant solution for popular sites requiring specialized protection.

Conclusions

Casa Batlló stands as an extraordinary example of thoughtful and meticulous design, characterized by its intricate details and unconventional forms [26], [27]. This remarkable architectural masterpiece showcases Antoni Gaudí's unparalleled creativity and innovative vision. The presented study demonstrates the extensive system of solutions and results of heritage conservation efforts at Casa Batló. Proper management of such a popular building requires appropriate management. The first aspect is the extraordinary amount of detail and complex structures that require preservation and protection. The second important aspect is the balance between accessibility and visitor crowds, which could negatively impact the building.

The presented study summarizes the potential of integrating Visual Twin solutions in the protection of architectural heritage but also in creating potentially multi-sensory and immersive experiences for visitors. For that, collecting such a vast amount of data from the building's documentation before beginning conservation work seems to be a very valuable approach. In this case, it led to a very thorough and groundbreaking process. Discoveries regarding the original colors offer a new perspective on Gaudí's vision. Despite the use of numerous modern technologies, conservation work is ultimately conducted using traditional tools to achieve a result as close as possible to the original elements.

Thanks to the data collected using modern technologies, new opportunities for visitors have been created. The facility's staff uses a beacon system to track live traffic. This allows for better crowd control while protecting the structure. Tablets during the tour allow for a more in-depth familiarization of the facility and the ability to present structures from previous years and Gaudí's inspirations. Activities undertaken under the theme of the 10D Experience go beyond simple guided tours.

Casa Batlló is an example of heritage management that respects tradition and craftsmanship while also utilizing modern technological tools. The successful integration of the Visual Twin at Casa Batlló exemplifies a holistic model for sustainable heritage management. It illustrates how digital innovation combined with traditional conservation theory can ensure that complex, multi-material monuments retain their authenticity, artistic value, and relevance for future generations.

References

[1] S. Mazzetto, „Integrating Emerging Technologies with Digital Twins for Heritage Building Conservation: An Interdisciplinary Approach with Expert Insights and Bibliometric Analysis," *Heritage*, vol. 7, pp. 6432–6479, 2024; DOI: 10.3390/heritage7110300.

[2] "Casa Batlló, New immersive visit and digital archive of Gaudí's works," Casa Batlló. [Online]. Available: https://www.casabatllo.es/en/news/new-immersive-visit/

[3] "Archiving of Documents linked to the Oeuvre of Antoni Gaudí," Heritage Volunteers. [Online]. Available: https://heritagevolunteers.eu/CoursesAndProjectsByTopics/DocumentationAndResearch/ArchivingOfDocumentsLinkedToTheOeuvreOfAntoniGaudai

[4] "Restoration," Casa Batlló. [Online]. Available: https://www.casabatllo.es/en/restoration/
[5] “Part 5 | The original colors,” Casa Batlló. [Online]. Available: https://www.youtube.com/watch?v=vPVnzNJAzqU
[6] “Part 4 | A trencadís puzzle,” Casa Batlló. [Online]. Available: https://www.youtube.com/watch?v=Boa9YDq2Ttw
[7] “Part 6 | The journey of the forge,” Casa Batlló. [Online]. Available: https://www.youtube.com/watch?v=8Akt25Vu0WY
[8] “Part 7 | The hidden wood,” Casa Batlló. [Online]. Available: https://www.youtube.com/watch?v=ihOX-qLJbyk
[9] “Part 8 | Metal jewels,” Casa Batlló. [Online]. Available: https://www.youtube.com/watch?v=LLs-2ec0jaE
[10] “Part 3 | The hidden garden,” Casa Batlló. [Online]. Available: https://www.youtube.com/watch?v=4UbuVkf0XTI
[11] “Living Architecture: Casa Batlló,” Refik Anadol. [Online]. Available: https://refikanadol.com/works/living-architecture-casa-batllo
[12] “Gaudí Chair,” Catedra Gaudí. [Online]. Available: https://catedragaudi.upc.edu/en/batches
[13] M. J. Diaz-Sarachaga, “May urban digital twins spur the New Urban Agenda? The Spanish case study,” *Sustainable Cities and Society*, vol. 114, Article Number: 105788, 2024; DOI: 10.1016/j.scs.2024.105788.
[14] “Refik Anadol: Gaudí Dreams,” Magazine Horse. [Online]. Available: https://www.magazinehorse.com/en/refik-anadol-gaudi-dreams/
[15] J. Gimeno, C. Portalés, I. Coma, M. Fernández, and B. Martínez, "Combining traditional and indirect augmented reality for indoor crowded environments. A case study on the Casa Batlló museum,” *Computers & Graphics*, vol. 69, pp. 92–103, 2017; DOI: 10.1016/j.cag.2017.09.001.
[16] M. Carrozzino and M. Bergamasco, “Beyond Virtual Museums: Experiencing Immersive Virtual Reality in Real Museums,” *Journal of Cultural Heritage*, vol. 11, pp. 452–458, 2010; DOI: 10.1016/J.CULHER.2010.04.001.
[17] Z. Gong, R. Wang, and G. Xia, „Augmented Reality (AR) as a Tool for Engaging Museum Experience: A Case Study on Chinese Art Pieces,” *Digital*, vol. 2, pp. 33–45, 2022; DOI: 10.3390/digital2010002.
[18] Z.Z. He, L. Wu, and X.R. Li, “When Art Meets Tech: The Role of Augmented Reality in Enhancing Museum Experiences and Purchase Intentions,” *Tourism Management*, vol. 68, pp. 127–139, 2018; DOI: 10.1016/j.tourman.2018.03.003.
[19] T. Jung and M. C. tom Dieck, "Augmented Reality, Virtual Reality and 3D Printing for the Co-Creation of Value for the Visitor Experience at Cultural Heritage Places,” *Journal of Place Management and Development*, vol. 10, pp. 140–151, 2017; DOI: 10.1108/JPMD-07-2016-0045.
[20] L. Neuburger, R.D. Egger, F. Salzburg, and R. Egger, “An Afternoon at the Museum: Through the Lens of Augmented Reality,” in *Information and Communication Technologies in Tourism*, R. Schegg and B. Stangl, Eds. Springer, 2017, pp. 241–254.
[21] “Casa Batlló announces Quayola as the next artist for its 2025 facade mapping in Barcelona,” Casa Batlló [Online]. Available: https://www.casabatllo.es/en/news/casa-batllo-announces-quayola-as-the-next-artist-for-its-2025-facade-mapping-in-barcelona/

[22] Y. Lu and J. Sádaba, “Kengo Kuma’s renovation of Gaudí’s Casa Batlló: A non-western designerly approach to addressing built heritage,” *The Design Journal*, vol. 27, pp. 988–1008, 2024; DOI: 10.1080/14606925.2024.2419717.

[23] Y. Lu, “A comparative study of two architectural reconstruction design of Casa Batlló,” *SHS Web of Conferences*, vol. 167, Article Number: 01009, 2023; DOI: 10.1051/shsconf/202316701009.

[24] “Casa Batlló pushes innovation in its tour with a new indoor localization system,” Casa Batlló. [Online]. Available: https://www.casabatllo.es/en/news/casa-batllo-pushes-innovation-in-its-tour-with-a-new-indoor-localization-system/

[25] S. Mazzetto, “Integrating Emerging Technologies with Digital Twins for Heritage Building Conservation: An Interdisciplinary Approach with Expert Insights and Bibliometric Analysis,” *Heritage*, vol. 7, pp. 6432–6479, 2024; DOI: 10.3390/heritage7110300.

[26] G.R. Collins, “Antonio Gaudi: Structure and Form,” *Perspecta*, vol. 8, pp. 63–90, 1963; DOI: 10.2307/1566905.

[27] D. Giralt-Miracle, "*Gaudi Esencial*." Barcelona: Librosdevanguardia, 2012.

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