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Review

Technologies for the Preservation of Cultural Heritage—A Systematic Review of the Literature

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Abstract: This work establishes the technological elements that have enabled the preservation, promotion, and dissemination of tangible and intangible cultural heritage in the period from 2018 to 2022. For this, a Systematic Literature Review (SLR) was conducted in the scientific databases Scopus, Science Direct, IEEE and Web of Science, which facilitated the identification of 146 articles related to the topic. A quantitative and qualitative analysis of the journals, authors and topics was carried out, detailing the important variables required to establish the sought-out elements; for this purpose, the following were quantified in the papers: type, topic, categorization, country, and language; in the publications, the type of heritage chosen, the place of the heritage and the type of intervention were investigated. The number of publications reporting the use of some type of technology was also identified, finding that 70% of them show a technological approach to preserve cultural heritage, while 30% refer to other types of interventions. The technologies reported to be used the most are 3D digital technologies (44% of those showing technological applications), augmented reality or virtual reality, henceforth AR/VR (15%).

Keywords: immersive virtual environments; 3D; cultural heritage

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1. Introduction

Cultural heritage is a term made known in the middle of the 20th century mainly by entities interested in its protection, such as the United Nations Educational, Scientific and Cultural Organization, hereinafter UNESCO, which defines it in its document resulting from the 1972 Convention for the Protection of the World Cultural and Natural Heritage held in Paris, as all tangible and intangible cultural expressions [1,2].

Intangible cultural heritage is defined by UNESCO in the same document as the practices, representations, expressions, and knowledge that a country or region recognizes as part of its cultural heritage [1].

Globally, many countries have been concerned about preserving, disseminating and teaching new generations the cultural and intangible heritages they have in their territories, and found the use of information and communication technologies a very valuable tool to achieve that goal; these tools have been applied to publicize traditional places [3], ref. [4] as well as to teach the cultural richness of a country [5,6], disseminate traditional symbols specific to the culture of each region [7,8], teach about traditional music and dances [9,10], and as a method of digital protection of cultural and intangible heritage [11,12].

Different technologies have been used for the preservation of cultural heritage in the world, and in order to provide information on what technological strategies can be implemented to promote tangible and intangible cultural heritage, this article analyzes the references that, from a technological approach, have some direct relationship with the promotion, dissemination and appropriation of heritage in general, with the purpose of making available to those interested, support to adopt good practices in future research work on the subject. To this end, a Systematic Literature Review (SLR) was carried out through the consultation and exhaustive filtering of 144 articles selected from different databases.

Based on the fact that information and communication technologies are fundamental allies for the preservation of tangible and intangible cultural heritage, their use has facilitated the emergence of a new paradigm in the conservation, preservation and dissemination of cultural heritage, known as Intelligent Heritage Management. This paradigm has as its objectives and fundamental pillars the use of technology for the application of preventive maintenance of heritage, the improvement of energy efficiency, the characterization of the profile of tourists and visitors, the increase in security and surveillance of heritage and the promotion of preservation and dissemination work at the service of the conservation and dissemination of cultural heritage. [13]

This document is structured in six sections. Section 2 describes the work related to the research topic. Section 3 presents the methodology applied for the present systematic review of the literature, implemented in two large sections: Section 4 presents the discussion and results, where an analysis is made from the scientometric variables and from the technical variables. The conclusions that led to this study are presented in Section 5. Finally, some proposals for future work are presented in Section 6.

2. Related Works

The preservation of tangible and intangible cultural heritage is a commitment that many countries have assumed, as evidenced in the different studies related to the subject, such as the one presented in [14], where a systematic literature review on 3D Technologies used for the preservation of intangible cultural heritage is performed, articles indexed in Scopus, Web of Science and IEEE Xplore databases were analyzed, where it is established that the most used technologies to preserve tangible cultural heritage are: 3D visualization, 3D modeling, Augmented Reality, Virtual Reality and motion capture systems.

In [15], an SLR was conducted on the use of social networks as a platform to promote the public participation process of heritage conservation, 248 articles were analyzed, and it was concluded that social networks expand the range of options for people to have a say in the decision process of cultural heritage management.

Likewise, in [16], a study was conducted with the objective of identifying different alternatives to preserve cultural heritage in the context of smart cities. To achieve this, a literature review was conducted in Google Scholar and Portal Capes, where 80 articles were analyzed; the study concluded that 3D scanning techniques, Building Information Modeling (BIM), mobile applications for integrated management of asset preservation and sensors for the acquisition and analysis of data from collections in real time are the most applied technologies in the contexts of smart cities.

In turn, in [17], a study is conducted where the ethical implications of technological interventions to preserve cultural heritage are reviewed, providing a framework to review and apply ethical concepts to improve the processes of "planning, recording, processing and dissemination of digital workflows for heritage preservation". This implies an appropriate use of digital heritage recording.

In [18], a review focused on techniques and technologies used in materials that are used for the conservation of material cultural heritage that does not affect the health of people; in this sense, articles published in the Scopus database are reviewed, using the keywords "nanoparticles", "leaching" and "coatings", as a result, important information is provided showing the best options for leaching with nanoparticles estimation that can be applied in the conservation of cultural heritage, such as building facades and bronze sculptures, among others.

Reference [19] presents a systematic literature review that addresses intangible cultural heritage and its relationship with urban resilience by searching the Scopus and Web of Science databases, where 94 articles were analyzed. The study shows that there are links between both areas of study and considers that ICH should be integrated into urban resilience discourses.

3. Methodology

SLR constitutes a valuable tool for the construction of state-of-the-art research; it allows the creation of frameworks on which future research is supported [20]; reference [21] cited by [22] defines it as a review that strives to comprehensively identify, evaluate and synthesize all relevant studies on a given topic.

There are different methodologies for conducting SLR. In [20], one of three stages is proposed: the first constitutes the definition of search parameters (definition of hypotheses, construction and validation of search strings), the second stage refers to the identification, compilation and debugging of information from the articles consulted and the final stage is the analysis of results from the compiled information.

An SLR similar to this has been raised in [23], but its approach has been more theoretical; it consists of three stages, the first consists of a review of electronic articles that allows the collection of relevant data. The second stage consists of analyzing and synthesizing the collected documents and writing the research results. Finally, considerations and conclusions are formulated.

For the development of this work, the methodology applied in [20] was selected. For the definition of the search parameters, initially, a preliminary literature review was conducted in the field of research (consulting documents such as reviews and overviews), which allowed the identification of the hypotheses that mark the horizon of this study and, with them raise the research questions whose answer will be sought throughout this work.

The research questions that served as a guide to narrow the search parameters and conduct the SLR were:

Q1-What types of interventions have enabled the conservation and preservation of the world's cultural heritage in the period 2018–2022?

Q2-What types of technologies have been used to conserve and preserve cultural heritage globally in the period 2018–2022?

Based on the above research questions, the key terms used for the construction of the search strings to be used in the SLR were identified (see Figure 1).

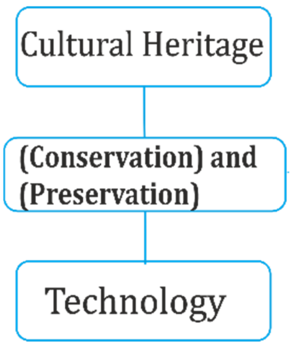

Figure 1. Diagram of the search chains built for the bibliographic compilation referring to the subject under study.

Figure 1 shows the scheme representing the search strings used, using as a particular focus in the thematic axes the words: "Cultural Heritage", "Conservation", "Preservation", "Technology".

The search strings constructed were validated in several specialized databases, which were selected from among the most recognized worldwide: Web of Science (WoS), Scopus, IEEE and Science Direct, which are related to the actuarial framework of the research that supports this article.

On the other hand, Table 1 presents the thematic axes considered and explains their combination strategies in the elaboration of the search strings. These combinations were used both in ascending and descending order.

Table 1. Thematic axes and combination strategies used in the review.

Thematic Axis 1	Thematic Axis 2	Thematic Axis 3
"Cultural Heritage"	Conservation Preservation	Technology
Link 1:	Thematic Axis 1 AND Thematic Axis 2	
Link 2:	Thematic Axis 1 AND Thematic Axis 3	
Link 3:	Thematic Axis 2 AND Thematic Axis 3	
Link 4:	Thematic Axis 1 AND Thematic Axis 2 AND Thematic Axis 3	

Thematic axis 1 is directed towards the different types of heritage, while thematic axis 2 is centered on the main theme, which is the conservation and preservation of cultural heritage. Thematic axis 3 is more specific to the term's technology. The strategy consisted of combining, in the different possible ways, these three thematic axes by means of the logical connectors AND, and OR, limiting them in time to the period 2018–2022 to ensure the observation window of interest is maintained.

With these search strings, we proceeded to the second stage. In this stage, the different articles downloaded from the specialized databases were compiled and filtered, eliminating duplicate articles and those that did not directly obey the purpose of the research.

With the previous step, 142 articles were compiled, and with them, a data acquisition matrix was constructed that documented for each article the scientometric and technical variables that will be described in the following section. The final stage consisted of developing different analyses based on the quantitative and qualitative evaluation of the documented variables.

The technical variables used to document the bulk of the articles and especially those directly related to technologies applied to the conservation and preservation of cultural heritage, were: (1) Type of heritage, (2) Location of the heritage, and (3) Type of intervention, which corresponds to the processes developed to preserve and/or conserve the chosen heritage. At the same time, other more specific technical variables were documented considering the type of technology implemented.

The last stage of the research is the discussion of the results and conclusions.

4. Results and Discussion

4.1. Scientometric Analysis

For the study of the 146 publications found in the previous step, the following variables were used as scientometric variables: number of articles published by each database, year of publication, publication medium (proceedings, journal or book, in the case of a journal, the quartile is identified), it was also considered important to identify the countries of publication, both of the journal or event and of the authors (country of the first author) and finally the language of publication, all of them considering the subject of interest, filtered according to the search strings described above.

This analysis began with the quantification of the publications found according to the databases. The databases considered were IEEE, Scopus, Web of Science, ScienceDirect, Scopus-Web of Science, and Scopus-Web of Science- Science Direct, as shown in Figure 2.

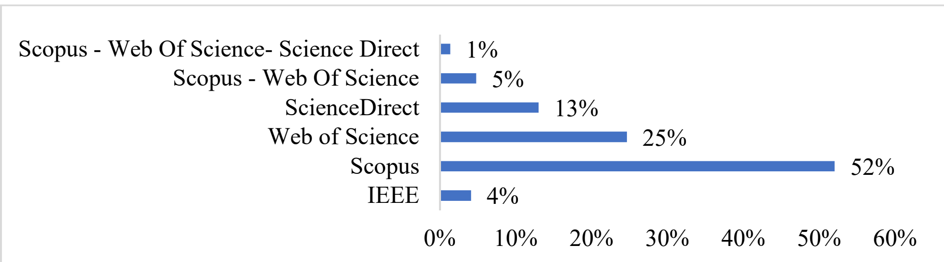

Figure 2. Number of publications: vs: Databases.

In Figure 2, it is identified that the scientific database with the highest number of publications found in the area of interest between 2018 and 2022 was Scopus, with 76 articles corresponding to 52% of the articles consulted. Scopus is one of the most accessed databases in the world; in addition, the focus of the articles published on this database is consistent with that of the present research.

From Figure 3, the subject studied shows a growing trend in terms of the number of publications per year since 2018; because this topic was of great interest to the academic community, it was still studied despite the global pandemic caused by the SARS-CoV-2 virus in the years 2020 and 2021. It is also evident that in the first months of 2022, publications on the subject continued to grow, which led us to believe that the trend would be maintained for the current year.

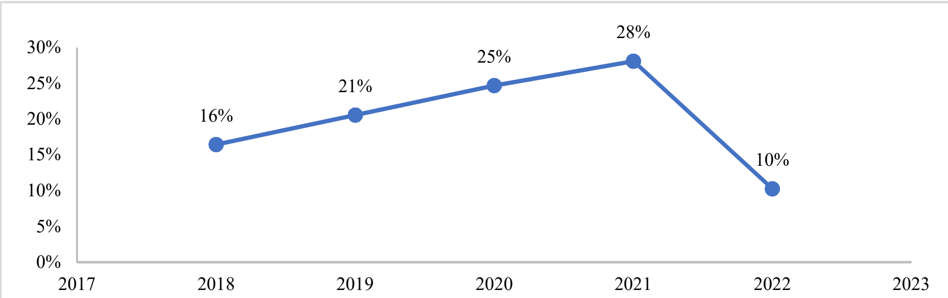

Figure 3. Number of publications: vs: Year of publication.

Regarding the number of publications according to the type of publication medium, the following were considered: proceedings, book chapters and those published in indexed journals.

Although only five book chapters were found, representing only 3% of the publications, it is clear from the results shown in Figure 4 that the topic is relevant for the scientific community in this area since, of the 146 publications analyzed, 100 (equivalent to 69%) have been published in indexed journals, which are usually specialized and have demanding evaluation systems, with more than one evaluator.

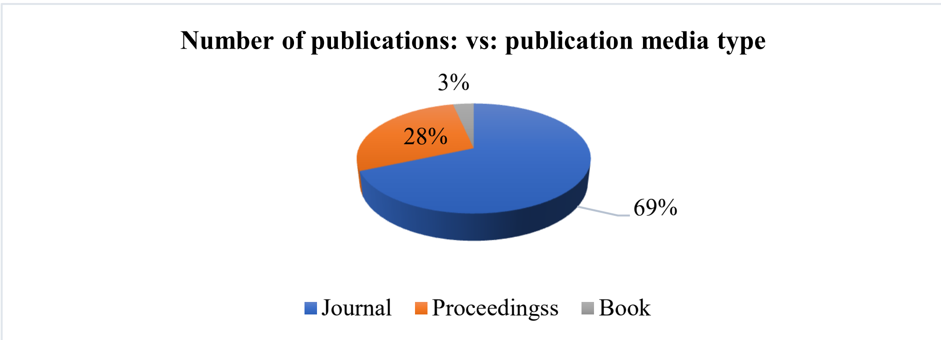

Figure 4. Number of publications: vs: Publication media type.

Normally, although the publications resulting from the presentation of papers at events are refereed, they are not categorized since they depend on the type of event, while books or book chapters go through the publisher's own evaluation systems. For this reason, in what follows, for the categorization of the publications consulted, only the number of publications found in specialized magazines or journals will be taken into account, which according to the graph shown in Figure 4, is 100. Of these, 90 journals were categorized, and 10 were not categorized, equivalent to 62% of the specialized publications consulted.

When analyzing these publications in journals that are categorized, it was found that 53 of them (corresponding to 59%) are categorized in Q1, 26 of them (corresponding to 29%) are categorized in Q2, 7 of them (corresponding to 8%) are in Q3, and the remaining

4 (corresponding to 4%) are in Q4. Figure 5 graphically shows the distribution described above, the categorization based on Scopus.

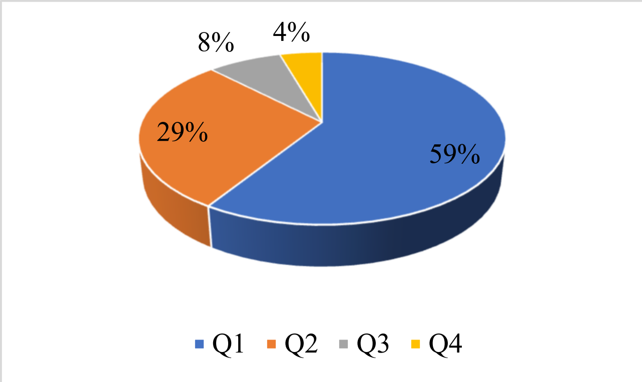

Figure 5. Number of journal publications: vs: quartile.

From the previous figure, it is very clear that the scientific community that publishes in this area has seen its work well valued since, due to its relevance and importance for the interested parties, it has been well categorized. The next scientometric variable analyzed was the country of origin of the first author of the articles.

Since many countries of origin were found for the first authors of the analyzed publications, it was decided to quantify the number of publications based on the countries with the largest number of authors. In Italy, there were 41 publications in the area of interest, equivalent to 28.1% of the total, followed by Spain with 15 publications (10.3%), and China with 14 publications (9.6%); the remaining countries with their respective number of publications and total percentage are shown in Figure 6: Algeria, Argentina, Austria, Bangladesh, Belgium, Canada, Colombia, Cyprus, Egypt, France, Germany, India, Iraq, Korea, Malaysia, Mexico, Pakistan, Shanghai, Slovakia, Slovenia, Sweden, Switzerland, Taiwan, Thailand, Ukraine, and the United Arab Emirates, whose individual contributions are minimal (but exist) and total 30 publications, which represent 20.5% of the publications studied.

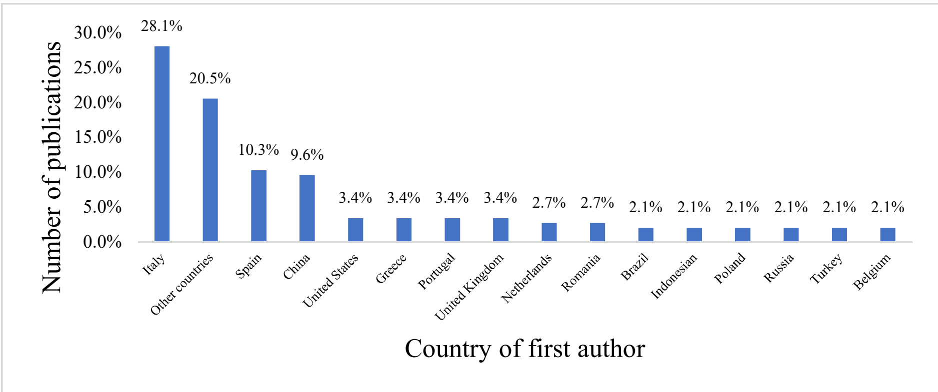

Figure 6. Number of publications: vs: country of the first author.

Regarding the number of articles according to the country of the journal publishing it, it was found that Germany is the country of preference for publishing on this topic, with 34 publications corresponding to 24% of the total, followed by the United States with 33 publications (representing 23%); in this case, the conglomerate of 14 countries gathered in a single item add up to 28 publications, which corresponds to 20%, but now the countries are: Austria, Belgium, Brazil, China, Egypt, Spain, France, Italy, Jordan, Poland, Romania, Serbia, Turkey and Ukraine.

With respect to the language of publication, English is the predominant language, making up 95% of the articles published (139 articles), followed by Ukrainian with 1 article, representing 1%; the remaining 3% are distributed among other languages, as shown in Figure 7.

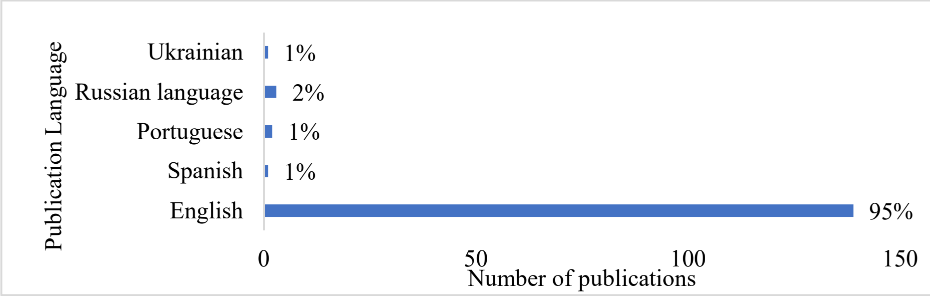

Figure 7. Number of publications according to the language of the paper.

Table 2. Journals with more publications.

Journal	Number of Papers	Quartile SJR	Quartile JCR	Area of the Journal	H-Index	ISSN	Country
Sustainability	17	Q1	Q2	Energy Environmental Science Social Sciences	85	2071-1050	Switzerland
Applied Sciences	6	Q2	Q2	Chemical Engineering Computer Science Engineering Materials Science Physics and Astronomy	52	2076-3417	Switzerland
Journal of Cultural Heritage	5	Q1	Q3	Arts and Humanities Chemistry Computer Science Economics, Econometrics and Finance Materials Science Social Sciences	64	1778-3674	France
Sensors	4	Q2	Q1	Biochemistry, Genetics and Molecular Chemistry Computer Science Engineering Medicine Physics and Astronomy	172	1424-8220	Switzerland

The SLR also identified the journals with the largest number of publications on the topic of interest; this is divided into journals and Proceedings. It was found that the journal of Sustainability from Switzerland had 17 published articles, followed by five articles each in the following: the Swiss journal of Applied Sciences and the Journal of Cultural Heritage from France. The complete information on these publications can be found in Table 2. It should be clarified that not all articles are analyzed; only the journals with the highest number of articles are presented.

4.2. Technical Analysis

The technical aspects to consider when analyzing different investigations are the types of technologies applied to preserve tangible and intangible cultural heritage, in addition to establishing the type of heritage that is most intertwined with technological processes.

Bearing in mind that cultural heritage is divided into tangible and intangible, it should be noted that the primary interventions are carried out for tangible cultural heritage, such as churches, [24] museums [25], buildings [26], sculptures, paintings [27], among others, of which 131 articles (92%) correspond to tangible cultural heritage, as shown in Figure 8 [28].

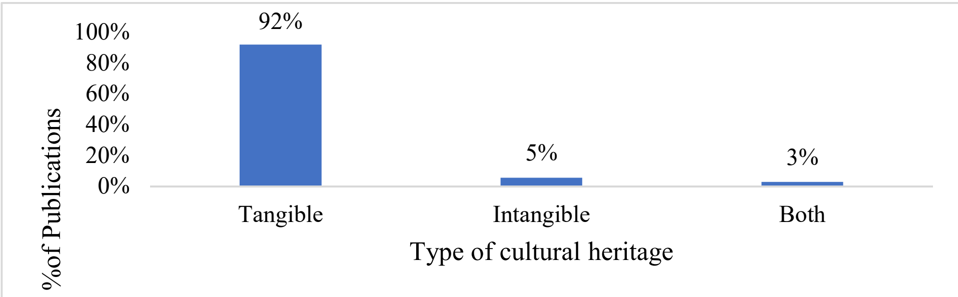

Figure 8. Number of publications according to the type of cultural heritage.

In developing the SLR, the best options for applying technology to the preservation of the tangible and intangible cultural heritage of humanity were analyzed.

Regarding the types of intervention documented to preserve cultural heritage, of the 146 articles analyzed, 70%, 102 are related to the application of different types of technology to preserve cultural heritage, as shown in Table 3.

Table 3. Type of intervention.

Type of Intervention	Number of Papers	%
Technological	102	70%
SLR	8	6%
Proposal	3	2%
Architectural	4	3%
Biological	1	1%
Not applicable	1	1%
Restoration	2	1%
Not applicable	4	3%
Educational proposal	2	1%
Chemistry	6	4%
Techno-pedagogical	1	1%
Political-administrative	1	1%
Renewable technologies (energy improvement)	1	1%
Administrative	1	1%
Microbiological	1	1%
Biotechnology	2	1%
Tourist proposal	1	1%
Economic	1	1%
Multidisciplinary	2	1%
Legal	1	1%

Of the 101 articles related to technological intervention, the type of technology applied was reviewed, showing that 3D modeling (44%), virtual reality and augmented reality, hereinafter AR/VR (15%), are the types of technologies most used to preserve cultural heritage, as shown in Table 4.

Table 4. Types of Technologies.

Type of Technology	Number of Papers	%
3D digital technologies	45	45%
Other technologies	34	31%
3D-AR/VR	17	17%
IoT	4	5%
Sensors	2	2%

Other technologies include gamification, digital restoration, social networks, the use of information systems, and different web technologies, among other technologies applied to preserve cultural heritage in different parts of the world.

Three Dimensional Digital Technologies

Three-dimensional digital technologies (3D modeling, 3D Scanning, 3D Visualization) are mainly widely used in the preservation of material cultural heritage; it has been applied in buildings of different types, such as castles [29–33], churches [34], sculptures [27], archaeological sites, [35,36] among others.

Table 5 shows the items that relate to 3D digital technologies. The heritage type item relates to whether it is natural, cultural or both; the heritage subtype relates to whether it is tangible, intangible, or both; and the final item is the specific heritage that has been chosen for the study. This same structure is used for the other types of applied technologies shown in Table 5.

Table 5. Articles on 3D digital technologies.

Reference	Database	Type of Assets Chosen	Subtype of Cultural Heritage	Country of Location of the Heritage	Chosen Heritage
[37]	Scopus	Cultural	Tangible	Greece	Rhodes Island
[29]	Wos	Cultural	Tangible	Portugal	Doge's Palace of Guimaraes
[27]	Wos	Cultural	Tangible	Italy	Colossus of Barletta
[30]	Wos	Cultural	Tangible	Italy	Palmieri Palace
[38]	Scopus	Cultural	Tangible	Not applicable	Not applicable
[39]	Scopus	Cultural	Tangible	Italy	Palazzo del Podestà in Mantua
[35]	Scopus	Cultural	Tangible	Italy	Archaeological site of the Roman waterway port of Aquileia
[40]	Scopus	Cultural	Tangible	Italy	The nine Sacri Monti of Piedmont and Lombardy
[41]	Wos	Cultural	Tangible	Poland	Centennial Hall in WroclawWang Temple in KarpaczSt. Gertrude Chapel in Koszalin Church in Iwiecino
[42]	Scopus	Cultural	Tangible	China	The city of Shigatse
[34]	Scopus	Cultural	Tangible	Spain	Basilica in the archaeological site of Baelo Claudia (Tarifa, Spain)
[43]	Science Direct	Cultural	Tangible e Intangible	China	Mogao Caves in Dunhuang and the Art of Guqin (Music and Murals)

Table 5. *Cont.*

Reference	Database	Type of Assets Chosen	Subtype of Cultural Heritage	Country of Location of the Heritage	Chosen Heritage
[44]	IEEE	Cultural	Tangible	Greece	Historic center of Rethymno
[45]	Scopus	Cultural	Tangible	Cuba	Historic Center of Havana
[26]	Scopus	Cultural	Tangible	Italy	Castillo de Serralunga d'Alba
[25]	Science Direct	Cultural	Tangible	Iraq	Iraqi National Museum Al-Mustansiriyah Heritage School
[31]	Scopus	Cultural	Tangible	Romania	Hida mansion dating from the 19th century
[46]	Scopus	Cultural	Tangible	Greece	Church of Zoodochos Pigi in the village of Vrisa
[47]	Scopus	Cultural	Tangible	Spain Vietnam Nepal	The Old Town of Ávila and its medieval walls The My Son Sanctuary Kathmandu Valley
[48]	Wos	Cultural	Tangible	Romania	Castillo Rakoczi-Banffy en Urmeni., Bistri.a Nasaud County
[32]	Scopus	Cultural	Tangible	Romania	Castillo de Corvin en Hunedoara
[49]	Scopus	Natural and Cultural	Tangible	China	24 National Scenic Areas
[50]	Scopus	Cultural	Tangible	Malaysia	Kota Bharu
[51]	Scopus	Cultural	Tangible	Italy	The city of San Ginesio
[52]	Scopus	Cultural	Tangible	Not applicable	Not applicable
[53]	Wos	Cultural	Tangible	Pakistan	Gorkhatri
[54]	Scopus	Natural	Tangible	Cyprus	The Neolithic settlement of Choirokoitia
[55]	Scopus	Cultural	Tangible	Mexico	Governor's Palace, located in the Mayan city of Uxmal-Yucatan
[56]	Science Direct	Cultural	Tangible	Slovenia	Dusk's homestead and Recica near Bled (Recica near Bled)
[57]	Scopus	Cultural	Tangible	Not applicable	Not applicable
[58]	Scopus	Cultural	Tangible	Not applicable	Not applicable
[59]	Scopus	Cultural	Tangible	Turkey	Suleymaniye Complex
[60]	Scopus	Cultural	Tangible	Italy	Archaeological heritage of the island of Sicily
[33]	Scopus	Cultural	Tangible	China	Mukden Palace: Dazheng Hall and the wooden structure of the Ancestral Temple
[61]	Science Direct	Cultural	Tangible	Tajikistan	South Khatlon
[62]	Science Direct	Cultural	Tangible	Not applicable	Not applicable
[63]	IEEE	Cultural	Tangible	Italy	Pavia

Table 5. *Cont.*

Reference	Database	Type of Assets Chosen	Subtype of Cultural Heritage	Country of Location of the Heritage	Chosen Heritage
[64]	Scopus	Cultural	Tangible	Algeria	The Mosque of the minaret of El Attik, the mausoleum of Scipio and the status of the fountain of Fouara
[36]	Scopus	Cultural	Tangible	Italy	Archaeological site of the Roman river port of Aquileia
[65]	Scopus	Cultural	Tangible	Thailand	Pagoda en Wat Maha That
[66]	Scopus	Cultural	Tangible	Egypt	Tutankhamun's tomb
[67]	Science Direct	Cultural	Tangible	United States	The Alamo San Antonio de Valero Mission
[68]	Scopus	Cultural	Tangible	Spain	Architectural heritage in Aragon
[69]	Scopus	Cultural	Tangible	Spain	the General Historical Library of Salamanca
[70]	Scopus	Cultural	Tangible	Romania	Dacian Embossed Disk from Piatra Ros

As shown in Table 5, the type of cultural heritage chosen by the application of 3D digital technologies is mostly cultural and tangible. Studies vary in the application of 3D digital technologies; some studies show this technology integrated with other types, as is the case for hyperspectral data for the estimation and evaluation of the degradation of materials used in heritage restoration by using geometric information point clouds and 3D meshes [37], the linking of the physical and digital world by combining Web-Gis, 3D and Internet of Things (IoT) technologies to preserve heritage buildings [69], proposals for virtual tours [57], simulations [63], which shows that it is the most used type of technology in preservation of cultural heritage especially material.

The chosen heritages vary in type and location; the Italian ones are the preferred choice, which corroborates what is shown in Figure 6.

From each of the articles related to the application of 3D digital technologies, the following technical variables were investigated: the Methodology implemented, which describes the steps used for the intervention; the Data Acquisition techniques, which establish the techniques used to obtain the information required for 3D modeling; the Data Acquisition Equipment, which corresponds to the different equipment used to obtain information; the Data Processing, which relates to the software tools used to process the information; and finally, the End Users, that relates to what type of users the intervention is directed at (i.e., Experts: are people, entities or institutions in charge of the protection of the cultural and natural heritage of humanity; Non-experts: are users and/or tourists who visit different heritages).

Review articles and those that do not specify the technical variables analyzed are excluded. The table with complete information is presented in the Appendix A (Table A1).

The main data acquisition methodologies found are in phases, where initially a survey of information is made, making use of different techniques such as photogrammetry [27,30,36,56] scanning (laser, optical or magnetic) [25,34,38,43,50,54,57,59,64] or a combination of both [37,41,45–48,51,55,60,65,66,68,70], and application of the BIM method [26,29,39–41,53,67,69].

Photogrammetry and terrestrial laser scanning are the main techniques to acquire data for 3D digital technologies [27,30,37,41,45–48,55,60,65,66,70]. Photogrammetry is mainly used due to the affordability of the devices (cameras) required, and in the case of laser scanning, together with suitable software, it is used mainly because of the speed at which it captures and processes data.

Regarding data processing, the most used programs for 3D modeling are Agisoft PhotoScan [37], Refs. [27,30,31,48,50,51,54,60] and Autodesk [26,41,51,53,56,57,59,68,70].

In [71], a comparison is made between these two software, highlighting the benefits of each one. They point out their preference for Autodesk because it has a free version for education, but this differs with what is shown in Table 6, where Agisoft Photoscan is used more despite being a proprietary software because it has no limits on the maximum amount of photographs to process, which allows quicker processing and excellent quality results.

Table 6. Articles on 3D-(AR/VR).

Reference	Database	Type of Assets Chosen	Subtype of Cultural Heritage	Country of Location of the Heritage	Chosen Heritage
[72]	IEEE	Cultural	Tangible	Korea	Tombs Koguryo
[73]	Scopus	Cultural	Tangible	Canada	One of the neo-Gothic window frames of the House of Commons in the Central Block of Parliament Hill National Historic Site
[74]	WoS Scopus	Cultural	Tangible	Not applicable	Not applicable
[75]	Science Direct	Cultural	Tangible	Palestine	the Mediterranean city of Nablus
[76]	Scopus	Cultural	Tangible	Mexico	Archaeological site of El Tepozteco
[77]	Scopus	Cultural	Tangible	Turkey Greece	Izmir in Turkey and Thessaloniki in Greece
[78]	Scopus	Cultural	Tangible	Myanmar	Myin-pya-gu Buddhist Temple in Bagan City
[79]	Scopus	Cultural	Tangible	Italy	Italian Catatumbas
[80]	WoS Scopus	Cultural	Intangible	China	Hainan
[81]	Scopus	Cultural	Tangible	Not applicable	Not applicable
[82]	Wos	Cultural	Tangible	Not applicable	Not applicable
[83]	Scopus	Cultural	Tangible	Indonesian	Palembang Historic Sites
[84]	IEEE	Cultural	Tangible	China	Fang Zhimin Martyrs Cemetery-red cultural relics in Jiangxi Province
[85]	Scopus	Cultural	Tangible	Italy	Egnatia Underground Cryptoporticus
[86]	Wos	Cultural	Tangible	United States	Princeton University Campus
[87]	Scopus	Cultural	Tangible e Intangible	Greece	Knossos Palace
[88]	Scopus	Cultural	Tangible	Greece	Brief History of the Museum

The end users of these interventions are mainly experts (78%), i.e., these types of interventions are carried out to obtain information that allows decisions to be made for the care and conservation of different heritages.

Virtual Reality/Augmented Reality (AR/VR)

As for the articles describing the use of AR/VR, they are presented in Table 6.

As in the previous case, the main chosen heritages are cultural and tangible, which confirms that they are the most protected by technological processes.

From the studies presented in Table 7, the following technical variables were analyzed: Data Acquisition Techniques, which establish the techniques used to obtain the required information; VR Software, which corresponds to the program used for the implementation of virtual or augmented reality; VR System, which corresponds to the level of immersion of the implementation (Immersive or non-immersive); Immersion Technology, which refers to the equipment used for the implementation of VR/AR; Data Acquisition Equipment, which relates to the different equipment used to obtain information; Data Processing, which relates to the software tools used to process the information; and finally, End Users, which relates to what type of users the intervention is aimed at (i.e., Experts: are people, entities or institutions in charge of the protection of the cultural and natural heritage of humanity, Non-experts: are users and/or tourists who visit the different heritages).

Table 7. Technical aspects of 3D-(AR/VR) articles.

Reference	Data Acquisition Technique	VR Software (Development)	VR SYSTEM	VR SET	Immersion Technology	Data Acquisition Equipment	Data Processing	End Users
[72]	Does not specify	A-frame	Non-immersive	App / PC of high denominations	Bookmarks supported in ARToolKit: Hiro marker	Does not specify	Does not specify	Non-Experts
[73]	Photogrammetry and T for building information modeling (BIM) combined with Augmented Reality (AR)	Vuforia Engine System Development Kit (SDK) for Unity	Non-immersive	App	Does not specify	Robot Who	Software Revit Software Rhino	Non-Experts
[76]	Photogrammetry	Does not specify	Non-Immersive	App	Holographic Device	Sony CyberShot Camera Model DSC-HX200V in RAW format-Provision device (Non-specific)	MATLAB	Non-Experts
[77]	Does not specify	Unity	Non-immersive	App	Does not specify	Does not specify	Does not specify	Non-Experts
[78]	Photogrammetry	Unreal Engine for Epic Games: Sistema Blueprints Visual Scripting	Immersive	High Denomination PC	(HMD) HTC	Cameras (non-specific)	Software Reality Capture	Non-Experts
[80]	C4D polygon modeling method	Motor UE4 Unreal Engine	Immersive	App / PC of high denominations	VR HTC + VIVE		SteamVR	Non-Experts
[84]	UAV aerial photography	Algorithm SIFT	Non-immersive	App / PC of high denominations	Does not specify	Does not specify	Algorithm SIFT	Non-Experts

Table 7. *Cont.*

Reference	Data Acquisition Technique	VR Software (Development)	VR SYSTEM	VR SET	Immersion Technology	Data Acquisition Equipment	Data Processing	End Users
[85]	Cartography Spheric photographs	Software Virtual Tour	Non-Immersive	High Denomination PC	Not applicable	Samsung Gear 360 camera is characterized by two 180° lenses on two sides (spherical head), a tripod and a led rod. Technical properties of the camera: Image sensor: CMOS, 15.0 MP ×2; Default output pixel (count equivalent to): 25.9 MP; Lens: f/2.2. Additional Photo Studio: Canon EOS 100D Digital Camera	Photoshop CC©	Non-Experts
[86]	Virtual tours and informational modeling (VT/IM)	Color Panotour Pro	Non-immersive	High Denomination PC	Not applicable	RICOH THETA S Camera		Experts
[87]	Virtual tours and informational modeling (VT/IM)	Unity 3D	Immersive	High Denomination PC	Supports all compatible VR headsets such as Oculus, HTC VIVE, Microsoft Mixed Reality and others.	HoloLens camera	SteamVR	Non-Experts
[88]	Smartphones	IOS: ARKit y Unity3D by Apple Android: ARCore by Google	Non-immersive	App	Not applicable	Smartphones and tablets		Non-Experts

Review articles and those that do not specify the technical variables analyzed are excluded. Table 7 shows the results.

Unlike the articles presented above (Tables 5 and A1), the application of AR/VR are more focused on non-expert users, i.e., they are mainly applications for visitors to interact virtually with the heritage, which contributes to its protection.

For these articles, photogrammetry stands out as a data acquisition technique [73,76,78,84] which establishes that for AR/VR applications, they prefer this technique to obtain the required images.

Around 77.78% of the applications are non-immersive in nature, 33% are accessed through an app for smartphones, an equal percentage are used through a high denomination computer, and the remaining 33% are accessed with both systems (App and high denomination PC).

The UE4 Unreal Engine is the software most used for visualization, among other reasons, because of the simplicity of its interaction, since you are not required to be an expert programmer to use it and also because of its fast rendering [73,78,80].

In [87], a study is presented where they develop an application that adapts the M.A.G.E.S. platform as AR to be used as VR in virtual museum applications.

It is very interesting how this application designs a device driver module to support all compatible VR headsets such as Oculus, HTC VIVE, Microsoft Mixed Reality and others. In addition, they use HoloToolK as API to integrate HoloLens to provide a Hologram service.

In [88], a study is presented for the creation of Cross/Augmented Reality applications for the Industrial Museum and Cultural Center in the region of Thessaloniki that can be replicated to showcase other types of cultural heritage.

IoT

Of the 146 articles analyzed, only four correspond to IoT technology, two applied in Italy, one in Spain and one in South Korea. The four articles correspond to tangible cultural heritage, as shown in Table 8.

Table 8. Articles on IoT.

Reference	Database	Type of Assets Chosen	Subtype of Cultural Heritage	Country of Location of the Heritage	Chosen Heritage
[89]	WoS Scopus Science Direct	Cultural	Tangible	Spain	the Church of Santo Tomàs and San Felipe Neri in Valencia
[24]	Scopus	Cultural	Tangible	Italy	San Domenico Church in Matera
[90]	Scopus	Cultural	Tangible	Italy	Heritage cities
[91]	Wos	Cultural	Tangible	South Korea	Woljeong Bridge

Table 9. Technical aspects of IoT articles.

Reference	Architecture Description	Architecture Components	Data Exchange	IoT System	Protocols Used	End Users
[89]	Modular, with flexible and low-cost nodes, sub-GHz based RF band, encrypted data exchange, based on IoT standards, Able to process transmitted and batch data collected by nodes and gateways, enables execution of processes embedded in cloud containers that consume data stored in the database (MongoDB)	Nodes, Gateway, Cloud, and User Interface	Sensor information reaches the collection cloud using MQTT rendering for LoRA and an https callback for Sigfox (as needed for this platform). The node information is separated into the two categories and stored in the corresponding record. A MongoDB database is used for storage.	Sensirion SHT3x sensor, low power with an accuracy of ±2% for HR and ±0.5 °Kelvin for temperature. 868 and 433 MHz ISM bands LoRaWAN band devices, 20 bytes per packet and 16.7 minutes between packets. The central node is an evaluation kit for the LoRA network that uses a multi-technology. mDot module. The rightmost node is an Arrow Smart everything evaluation kit that includes a Telit LE51-868S module for Sigfox. Multitechs Multiconnected Conduit MTCDT-210A Gateway, IBM Bluemix PaaS Cloud MultiConnect Router/Gateway CONDuit MTCDT-210A and accessory card for LoRa	Sigfox LoRaWan	Non-Experts

Table 9. *Cont.*

Reference	Architecture Description	Architecture Components	Data Exchange	IoT System	Protocols Used	End Users
[24]	Modular, developed on a stack of IP and UDP (User Datagram) protocols with the reuse of the application layer DLMS (Device Language Message Specification)-COSEM (Companion Specification for Energy Metering) already defined by CEI (Comitato Elettrotecnico Italiano) and IEC (International Electrotechnical Commission). Commercial radio modules (TIM+Fasweb+Huawei) implement the NB-IoT + IP + UDP protocol stack at the embedded level.	(1) A sensor network (2) A gateway module that handles the dialog between the sensor network and the data management server; (3) A data management server (Big Data). (4) A user application.	WSN network (wireless sensor network) 5G, to connect the WSN to the NB-IoT 5G network, an interface was created using the M2M communication service between the local MODBUS gateway and the MODBUS -NB-IoT gateway of the 5G network, thus allowing the transmission of the collected data to the servers of the TIM IoT cloud platform.	10 linear displacement transducers, 5 inclinometers, 2 internal temperature and humidity sensors, and 1 external temperature, humidity and pressure sensor	IP and UDP (User Datagram) The RS485 interface with MODBUS RTU protocol Mobile line: NB-IoT 5G	Experts
[90]	Not applicable	Not applicable	Not applicable	Not applicable	LoRaWan Constrained Application Protocol (CoAP)ZigBee	Non-Experts
[91]	IoT unit: Community sensing sensor (100 environmental sensors in ZigBee wireless environment + 5 slope measurement sensors) and communication unit + application.	The IoT unit (includes a detection unit), a communication unit and an application part.	IoT unit (includes a sensing unit), a communication unit and an application part. Sensors collect information + Server (Linux environment) + Wireless ZigBee for receiver and DB (SQL). Data stored in real time.	Detection unit: 100 structural and environmental sensors. Co sensors consist of 2: Slope measurement 2: Structured load measurement The devices are equipped with bullet elements. The resolution of the integrated analog-to-digital converter (ADC) is 16 bit	ZigBee with a communication interface Industrial, Scientific and Medical (ISM) radio band 2.4 GHzRS485	Experts

From the studies presented in Table 8, the following technical variables were analyzed: Description of the Architecture, which corresponds to a brief synthesis of the IoT architecture presented in the article; Components of the architecture, which describes the elements that make up the architecture presented; Data Exchange, which describes how the information is handled within the architecture chosen; IoT System, which refers to the equipment used for the implementation of IoT technology; Protocols Used, which relates the different IoT protocols used in the implementation; and finally, End Users which relates to what type of users the intervention is aimed at (i.e., Experts: Are people, entities or institutions that are responsible for the protection of the cultural and natural heritage of humanity, Non-experts: are users and/or tourists who visit the different heritages).

Review articles and those that do not specify the technical variables analyzed are excluded. Table 9 shows the results.

As can be seen in Table 9, the platforms with IoT technologies designed for cultural heritage protection are very similar in their architecture; basically, they use nodes, gateways and a user interaction layer [89–91]

The main IoT protocols used in terms of short-range networks are 5G and ZigBee [90,91]. For long-range networks, the most widely used is LoRaWan [89,90].

Around 50% of the articles on IoT are addressed to expert users, and the other 50% to non-experts.

5. Conclusions

By means of a strict SLR based on the approach of carefully designed search chains to debug publications, 146 articles were filtered from which a description was made of the technological elements for the promotion, dissemination and appropriation of cultural heritage at a global level in a 2018–2022 observation window. For this review, several databases were carefully selected from among the most used for international publications, finding that most of the articles are published in specialized and indexed journals, duly categorized, most of them in Q1, in journals mostly from the USA and in English.

In response to the questions posed regarding the type of intervention that has enabled the conservation and preservation of the cultural heritage of humanity in the period between 2018–2022, Table 3 shows that cultural heritage intervention has been achieved from different approaches, where it stands out that the main interventions are technological (70%) and architectural (6%).

Regarding the second question, the types of technologies that have been used to conserve and preserve cultural heritage globally in the period between 2018–2022 are mainly 3D digital technologies (encompassing 3D modeling, 3D Scanning, 3D Visualization), AR/VR (immersive and non-immersive) and IoT platform configuration.

The use of technology to preserve tangible and intangible cultural heritage constitutes smart cultural heritage management, a term widely used worldwide.

From the above, it can be concluded that the technological elements and resources available today allow the inclusion of technology as a tool to contribute to the preservation of cultural elements and intangible heritage.

6. Future Work

Based on the results, recommendations for future research are made. The first relates to the application of technology for the preservation and dissemination processes of intangible cultural heritage, as in the case of Colombian vallenato and Spanish flamenco.

The second recommendation consists of the deepening of educational processes implemented to preserve intangible cultural heritage.

Considering Figure 8, 92% of the implementation of technological solutions is mainly in tangible heritage; it would be interesting to deepen the implementation of technology for the protection of intangible heritage in general.

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Appendix A

Table A1. Technical aspects of 3D digital technologies articles.

References	Data Acquisition Methodology	Data Acquisition Technique	Data Acquisition Equipment	Data Processing	End Users
[37]	Initial modeling (M1): geodetic, photogrammetric and laser scanning data Spectral system:	Photogrammetry Magnetic Scan	M1: Two total integrated stations (Pentax R323NX and Leica TCR 405), two time-of-flight pulse-based 3D laser scanners (Leica BLK 360 and Faro HDR), two full-frame DSLR cameras (Canon EOS 6D and Sony A7RIII) with multiple lenses (24 mm, 135 mm, 28–75 mm) and two unmanned aerial systems (DJI Phantom 4 Pro and Mavic 2 Pro). Hyperspectral: HyperView multi-sensor hyperspectral sensing platform using 3D-one	Software Agisoft Metashape v.1.6.5 Software Geomagic Wrap 2017. Software Faro Scene and Cyclone Register 360 (BLK Edition) applying the Cloud-to Cloud method	Experts
[29]	Application of the HeritageCare project with all its protocols (SL1, SL2, SL3) SL1: advanced monitoring system to keep specific structural and environmental parameters under control.	BIM	SL1: 12 temperature and relative humidity (TH), 7 surface and 5 environmental sensors, plus 5 sensors for surface temperature, relative humidity and luminosity (THL). Three xylophagous sensors (X). One carbon dioxide (G) sensor. 2 biaxial clinometers (CL). One weather station (EM) BIM model: Autodesk Revit Virtual Virtualization Tour: HoloLens	HeritageCare Platform Autodesk Revit Software	Experts/Non-experts
[27]	The phases of the FEM analysis: (i) construction of the 3D model; (ii) transformation of NIF into a quad mesh model and NURBS; (iii) WEF analysis. Phases of the Photogrammetric Model: (i) alignment of the images; (ii) building of a dense point cloud (PC); (iii) the construction of meshes and the identification of the plans of the single façade; (iv) the construction of the ortho mosaic.	Fotogrametría	Topographic survey: Total station: Leica TS11. EDM measurements are performed using laser technology (Light Amplification by Stimulated Emission of Radiation) Scan to FEMSLR camera. Nikon D3300 with a Nikkor 20mm f/2.8D prime lens. Intel(R) Xeon(R) E5-1650v4 @ 3.60 GHz CPU (central processing unit), RAM (random access memory) 64 GB, NVIDIA Quadro M4000 GPU (graphics processing unit).	Software Rhino Software Cloud Comparison Software Agisoft Metashape Software Midas Fea NX	Experts
[30]	Data acquisition (photogrammetry) Information Analysis-3D Modeling Using Analysis Software Calculating the severity index	Fotogrametría	Processing: Computer with dual Intel Xeon processor (128 GB RAM, 64-bit operating system). Standard Level Cameras, Carbon Fiber Telescopic Rod, Tripod, Tablet, Laser Distance Meter, Flexometer, Tweezers	Software Agisoft Photoscan Software 3D microscopy analysis software (such as TalyMap 3D), Microsoft Excel software	Experts
[38]	Exhibition platform (mirror) Three-dimensional (3D) scanning to build a digital database of the original shapes.	Optical scanning	High-resolution optical scanner for creating 3D models	3D printing for scientific exhibition	Non-experts

Table A1. *Cont.*

References	Data Acquisition Methodology	Data Acquisition Technique	Data Acquisition Equipment	Data Processing	End Users
[39]	Implementation of the INCEPTION platform: innovate 3D models "forever", "for everyone", "everywhere", developing, collecting and sharing interoperable 3D semantic models. Cloud-based platform.	BIM	The BIM model allows the use of any software such as Autodesk Revit, ArchiCAD, Apache Fuseki SPARQL Dedicated Server.	Input = BIM model loaded as IFC (Industry Foundation Class) processed under Windows. Semantic information is extracted and generated as (RDF), according to the INCEPTION H-BIM ontology, serialized as Turtle (TTL), stored and accessed as HTTP through a dedicated server.	Experts
[35]	A segmentation process was carried out in the chosen sector using the EasyCUBE PRO software of the Geomaticscube Ecosystem (Geomaticscube, 2018)		Software tool called "Working Box" allows you to define the minimum rectangular parallelepiped (box) capable of enclosing a 3D object.	EasyCUBE PRO software from the Geomaticscube ecosystem (Geomaticscube, 2018)	Experts
[40]	Knowledge: 3D Survey Techniques Modeling Methods and modalities of access and web exchange of multiscale 3D reconstructions.	BIM	Online information system, data provided by the Politecnico di Milano.	Modelo 3D: BIM technique. BIM3DSG7:1. Database creation (DB). PostgreSQL Software PgAdmin.	Experts
[41]	Application of different data acquisition techniques for 3D modeling and literature analysis to formulate guidelines for the implementation and organization of the BIM and HBIM process for cultural heritage objects	Project 1: Terrestrial laser scanning-Photogrammetry Project 2: Laser scanning Project 3: Photogrammetry Project 4: Laser scanning and photogrammetry BIM	Project 1: Faro X330 ScannerProject 2: Z+ F SCANNER IMAGER 5010cProject 3: NIKON D200 digital camera and AF S NIKKOR objective Project 4: FARO FocuS 150 ground scanner, complemented by drones with 6K Cinema DNGRAW digital cameras.	P1: Autodesk ReCap, AutoCAD, Revit, Meshlab-BIM model: Software: FARO SCANE, Geomagic Design X, Rhino Ceros P2: Revit Software, Laser Control Software, ArchiCAD, Software pointcab P3: Software Photomodeler Scanner Rino Software P4: Reality Capture Software. Unity CAD Program (3D)	Experts
[34]	Terrestrial laser scanning (TLS) for data acquisition is processed using software, and a massive point cloud of approximately 426 million points is obtained for 18.27 GB file in PTS format.	Terrestrial laser scanning (TLS)	TLS: Leica Geosystems BLK360 3D scanner [42], maximum range of 120 m (radius of 60 m), spot measurement speed of 360,000 points per second and accuracy of 4 mm at 10 m	Leica Cyclone REGISTER 360 software on a laptop via the scanner's Wi-Fi network	Experts
[43]	Elaboration of a digital replica of the Heritage with photographs. Digital printing with 3D to capture murals in the caves and print them on the walls of a physical replica of the cave. Digital wall staging: (1) image segmentation; (2) damage labeling; and (3) content filling.	Material heritage: high-precision scanning and photography. Intangible heritage: phonological coding method	Flying Sky gigapixel camera	A priori algorithm and the Suffix Array structure	Non-experts

Table A1. *Cont.*

References	Data Acquisition Methodology	Data Acquisition Technique	Data Acquisition Equipment	Data Processing	End Users
[44]	Application of GPR to examine the ability of the method to detect cracks and changes in the thickness of the heritage wall, implementing 4 phases of measurements, making use of GPR Noggin	GPR (Ground Penetrating Radar)	GPR Noggin (Sensors & Software) is equipped with 250 MHz and 500 MHz antennas. Synthetic GPR models and scans were performed using the finite difference time domain (FDTD) method via the free gprMax software	Matlab: Crewes Matlab Toolbox	Experts
[45]	(1) Collection of information through photogrammetry and TLS (2) Data processing by specialized software (3) Production of 3D surface model.	Photogrammetry Solar Laser Scanning (TLS)	SLR cameras, compact cameras, tablets, smartphones	Zephyr Aerial 3DF Raster Graphics Editing Software	Experts
[26]	(1) Data: HBIM method, photogrammetric study integrated with GNSS (Global Navigation Satellite System) study (2) Modeling, HBIM, for VR model (3) Features of the VR model route (4) Preliminary Evidence (5) Development of a serious game	Fotogrametría HBIM	An omnidirectional camera called RICOH THETA. Shader Skybox/3D Panoramic Unit	BIM-based Autodesk Revit VR platform: Autodesk LIVE and Enscape-Game engine: Unity	Non-experts
[25]	Two fine recording methods were applied: the nearest iterative point to the nearest neighbor (NN-ICP) and the nearest Levenberg-Marquardt iterative point (LM-ICP). 3D modelado. A comparison is made between these two methods.	Terrestrial laser scanning (TLS)	Reference Data Contrast: Topcon ES 105 Total Station TLS Device: Stonex X300 TLS Scanner	CAD modeling software.	Experts
[31]	Analysis, data acquisition, 3D modeling and spatial analysis in the GIS environment.	UAV method combined with ground control points (GCPs)	Image: DJI Mavic Pro drone UAV-based camera equipped with a 4K camera, manufactured by Da-Jiang Innovations Science and Technology Co and a stabilizer camera base head.	Software Agisoft Photoscan Metaforma BIM Technique Software ArchiCAD Motion Software Structure (SfM)	Experts
[46]	Data acquisition (3D laser scanning and UAV photogrammetry) Data processing (two data sets) Comparison of the two data points.	Fotogrametría Ground Laser Scanning (TLS)Unmanned Aerial Vehicles (UAVs)	Faro Focus 3D S120UAV laser scanner: Phantom 4 manufactured by DJI. The quadcopter has an integrated camera with a CMOS sensor (1/2.3 inch) of 6.17 mm wide and 3477 mm long and a resolution of 12Mpx	Software DJI GS pro software FARO SCENE software ContextCapture software CloudCompare	Experts
[47]	Review of geoinformatics technologies in photogrammetry, remote sensing and spatial information science and their application to HC	Terrestrial Laser Scanning Photogrammetry (TLS)	Non-professional Single Lens Reflex Laser Scanner Faro Focus 3D S120	Leica Cyclone 3D processing software. Online geo-crowdsourcing platform	Experts

Table A1. *Cont.*

References	Data Acquisition Methodology	Data Acquisition Technique	Data Acquisition Equipment	Data Processing	End Users
[48]	(1) Identification of milestones S, T and D (2) The establishment of 3D topography and modeling of heritage objects. (3) Planimetric support hitos (4) Creation of the initial GNSS (5) Establishment of GCP (6) Thickening of the planimetric network GCP (7) distribution of elevations to GCP planimetric milestones (8) Red GCP completada (9) Levantamiento fotogramétrico terrestre	Ground laser scanning (TLS) and aerial photogrammetry performed with an unmanned aerial vehicle (UAV)	Photogrammetry: Nikon D5100 18–55 VR Drone Kit DJI Phantom 4 Digital Camera, with the following features: Camera sensor: 1″ CMOS; Resolution: 20 mpixels, Lens: FOV 84°; 8.8 mm/24 mm TLS scanner: Z + F (Zoller + Frochlich) Imager 5010	Software Agisoft Photoscan Software CloudCompare Software Z + F Laser Control® Office y Scout Software CAD	Experts
[32]	Satellite data collection-software data processing-3D modeling	Persistent dispersive interferometry (PS-InSAR)	Persistent dispersion interferometry: Image: Copernicus program: 20 images acquired by Sentinel-1A and 21 images of Sentinel-1B downloaded free of charge from the Copernicus Open Access Hub. Digital modeling: Scout LiDAR sensor (Velodyne Ultra Puck VLP 32C) and a Sony A7R II camera, both mounted on a DJI Matrix M600 PRO UAV platform.	Software ENVI SARscape Software Phoenix LiDAR Systems Software Global Mapper	Experts
[50]	The three main stages consisted of data preparation, data preprocessing, and main processing.	Ground laser scanning (TLS) and unmanned aerial vehicles (UAVs or drones) 3D Geoinformation System (GIS)	Professional Multirotor Fixed Wing UAV DJI Phantom 3 Laser Scanner Topcon IP-S3 HD Mobile Mapping System 3Descarners Laser (GNSS)	Magnet Master Field, TopconMagnet Collage, Topcon Software Agisoft photoscan City Engine, software ESRI	Experts
[51]	(1) Acquisition of geometric and photogrammetric data and analysis of the conservation status of the selected portion (2) The formalization of the ontology for the conservation process. (3) 3D modeling. (4) The enrichment of parametric model data.	UAV (Unmanned Aerial Vehicle) digital photogrammetry and SLAM (Simultaneous Localization and Mapping) handheld laser scanner	GPT3105N como estación total. DJI Spark MMA1 drone y su cámara integrada RPAS (Remotely Piloted Aircraft Systems). Slam MLS (Mobile Laser Scanner) KAARTA Stencil 2 Scanner	Agisoft Metashape Software version 1.5.3 CloudCompare Software. Autodesk Revit Software	Experts
[53]	Data acquisition (LiDAR method) Generated Point Cloud Mapping (BIM) Resource collection, Cleansing collected data, saving in format(.csv), and converted to XML format by Top braid Composer to be replicated with Autodesk Revit and AutoCAD Ontology Design	LiDARBIM scanning method	Does not specify	AutoCAD Autodesk Revit (BIM environment)	Experts

Table A1. *Cont.*

References	Data Acquisition Methodology	Data Acquisition Technique	Data Acquisition Equipment	Data Processing	End Users
[54]	Two types of GNSS receivers were used for data acquisition: (a) 3 Trimble R9 equipped with Zephyr 2 geodesic GNSS antennas and (b) a Leica GS15 smart GNSS receiver.	UIAV magicians and laser scanning	Trimble R9 equipped with Zephyr 2 geodesic GNSS antennas and (b) a Leica GS15 smart GNSS receiver Image acquisition: DJI Inspire 2 UAV, with a 24 MP camera	Software Agisoft PhotoScan Professional	Experts
[55]	Inspect the building and obtain morphological data, at an adequate and quantifiable scale, together with complementary chromatic information that allows a high-quality definition of the external texture of each of its parts.	Fotogrametría Solar Laser Scanning (TLS)	Laser Scanner Faro Focus 3D S120 Canon 5D Camera Mark lll DSLR with Canon EF 24–105 mm f/3.5-5.6 IS STMP Lens OpCard 202Onnon DL-913/DL-Simple Model LED Continuous Light and Tripod Lens	Does not specify	Experts
[56]	(1) Extraction of data from the conservation plan. (2) classification of data to be included in the BIM model. (3) Modeling of base data to include them in BIM (4) Translation of the data model to be implemented in the chosen software	Fotogrametría HBIM	Does not specify	Software Autodesk Revit	Experts/Non-Experts
[57]	(1) Creation of 3D models. (2). Formation of ontology. (3) Creation of 3D GIS for onto-model integration (4) Formation of ontological excursion routes	Recommended: UAV imaging and laser scanning	Recommended: tripod and a special panoramic head, digital camera, lens (wide-angle or fisheye type), camera shooting cable	Recommended 3D modeling: Real Works Survey (RWS) software, three-dimensional development 3Dipsos: Autodesk Inventor software, Autodesk Revit 3D	Experts
[59]	(1) Data acquisition by terrestrial laser scanning (2) Recording and georeferencing scans (3) Point cloud segmentation into tiles (4) Rearranging point cloud tiles (5) 3D solid modeling (6) texture mapping of polygon models, (7) Conversion of data for import into the game engine (8) development of motion and interaction control in Unity (9) implementation on HTC Vive (10) immersive and interactive visualization of the Complex	Terrestrial laser scanning (TLS)	Riegl VZ400 scanner with Canon EOS 7D mk II Nikon D610 camera with 20.2MP CMOS sensor. RiScan for georeferencing and segmentation of point clouds ReCap for reorganization of tiles3ds Max using segmented point clouds for 3D modeling and texture mapping Unit game engine Visualization: HTC Vive VR system that uses Steam VR as an interface between the game engine and HTC Vive.	Software Autodesk 3D Max	Experts
[60]	Data acquisition (3D laser scanning and photogrammetry) Data processing 3D modeling visualization	Fotogrametría Solar Laser Scanning (TLS)	Active sensors (laser scanner) and passive sensors (digital camera) Professional SLR camera	Software Agisoft PhotoScan Visualización: 3DHOP (3D Heritage Online Presenter	Experts

Table A1. *Cont.*

References	Data Acquisition Methodology	Data Acquisition Technique	Data Acquisition Equipment	Data Processing	End Users
[61]	CAAL satellite remote sensing	Remote sensing data: very high resolution (VHR) images available through Google Earth and Bing Imagery, transmitted within the QGIS platform	CORONA Satellite	Does not specify	Experts
[63]	(i) 3D reproductions for the implementation of augmented reality; (ii) interaction of the gaze and gestures for the realization of applications to improve the visitor experience in the exhibitions; (iii) AI applications for the realization of useful tools/solutions for the restoration of works of art.	Natural User Interfaces (NUI)	Eye-tracking system: consists of a common PC, a Full HD 24 display and an EyeTribe device (ET100-The Eye Tribe Tracker 11) Application based on gesture interaction: a standard PC, a 24″ Full HD monitor and a Kinect sensor	Does not specify	Non-experts
[64]	(1) Workflow organization (2) Section control (3) 2d fusion (4) representation. Documentation and study of mechanical behavior through 3D modeling: Data collection in the field and data processing.	3D laser scanner	Does not specify	Escanear Word	Experts
[36]	Application of HBIM techniques to obtain the 3D Model of the chosen heritage, the data obtained are transferred to the EasyCUBE PRO software to be processed (Segmented) and obtain the analysis of patrimonial degradation.	Fotogrametría digital	They do not specify	Software EasyCUBE Pro	Experts
[65]	Based on the hierarchical orientation of the images through an artificial vision technique. To automate image-based modeling and produce high-quality 3D point clouds. Three-dimensional point clouds, textured meshes and orthoimages were created.	Digital Photogrammetry Ground Laser Scanning (TLS)Unmanned Aerial Vehicles (UAVs)	DJI Inspire 1 Pro UAV platform, Zenmuse X5 digital camera equipped with a global navigation satellite system (GNSS) and an interchangeable lens that can be operated in real-time cinematic mode (RTK). Riegl LMS-Z210 Scanner (for TLS)	Pix4D CloudCompare Software (To compare the results of two applied techniques)	Experts
[66]	Making a replica of Tutankhamun's tomb using a high-resolution two- and three-dimensional capture of the images of the original tomb. The print of the images was vacuum filled on a base of milled and molten resin to be assimilated to the surface contours of the original wall.	Laser scanning and photogrammetry	Does not specify	Does not specify	Non-experts
[67]	Recopilation and data processing, Identification of historical details, Constructing of parametric historical objects and mapping of parametric objects in scanning data to produce complete engineering orthographic drawings and 3D models.	Laser scanning HBIM	Artificial Intelligence "AI" sensors and cameras	HBIM and IoT tools	Experts

Table A1. *Cont.*

References	Data Acquisition Methodology	Data Acquisition Technique	Data Acquisition Equipment	Data Processing	End Users
[68]	Use of the platform: (1) Geometric modeling (2) Server usage (3) Visor"	Photogrammetry Magnetic Scan	Photogrammetry: Nikon F-810 camera and wide angle of 17 mm. (104°) and 24 mm (83°). Laser Scanning: laser scanner of the brand Faro, model Focus 150	PetrobimPhotoscan web platform Autodesk Recap Software Open Source Cloud Comparison	Experts
[69]	Application of the HeritageCare System: SL1 or StandardCare; SL2 or PlusCare. SL1, evaluates the state of the heritage SL3 or TotalCare: integrates and manages all data collected from SL1 and SL2 using BIM Modeling	BIM	HeritageCare platform, developed in PHP and JavaScript, HTMLy CSS (design language), among other web systems. To obtain information from the sensors using JavaScript Object Notation (JSON) communication protocol between the platform and the server that stores the monitoring data.	Application of the PlusCare protocol on the HeritageCare platform	Experts/Non-Experts
[70]	3D Scanning	Photogrammetry laser scanning	Creaform Go! Scan 50	Autodesk Mudbox CATIA V5	Experts/Non-Experts

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