applied sciences

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Good Practices in the Use of Augmented Reality for the Dissemination of Architectural Heritage of Rural Areas

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Abstract: When it concerns dissemination, the relationship between cultural heritage and technology has not always been easy. On the one hand, the emotions involved in knowing, enjoying, and feeling a real heritage remain should not be eclipsed by the technological experience. On the other hand, technology cannot be relegated to the point where its use is so superficial as to make it irrelevant. Hence, in the search of good practices in the dissemination of cultural heritage, it is essential that interdisciplinary work teams, composed of humanists and technicians, design new experiences that try to achieve a balance between what must be shown and the way in which it is done. This paper aims to show the potential of augmented reality (AR) for the dissemination of cultural heritage, since it allows the perceiving of real remains while offering virtual reconstructions and complementary information, sounds, images, etc. A bibliometric analysis focusing on its use for the preservation of the memory of vernacular architecture is made. Then, from the understanding and interpretation of the ideas exposed in literature, a decalogue of good practices in the use of AR for architectural heritage is established considering the holistic perspectives that any dissemination initiative must have. These initiatives can attract people to rural areas and contribute to the improvement of their social and economic situation. As an example, a proof of concept of an AR experience is presented at the end of the paper.

Keywords: IT in cultural heritage; augmented reality; 3D modelling; cultural heritage dissemination; modern exhibition techniques

Citation: Merchán, M.J.; Merchán, P.; Pérez, E. Good Practices in the Use of Augmented Reality for the Dissemination of Architectural Heritage of Rural Areas. *Appl. Sci.* **2021**, *11*, 2055. https://doi.org/10.3390/app11052055

Academic Editor: Marek Milosz

Received: 27 January 2021
Accepted: 20 February 2021
Published: 25 February 2021

1. Introduction

One of the main problems that administrations of developed countries are facing today is the depopulation of rural areas. Concerning this, the concept of "empty Spain" has emerged in our country to define those regions with a worrying rural population drift. The "emptied" territories (both Castile and Extremadura, mainly) have alarmingly low population densities in a society that is growing older. In these territories, countless villages and small towns have been abandoned since the middle of the last century, and many others have been worryingly losing population for decades.

The emigration of peasants that began in the mid-20th century, the generalisation of higher education that gave rise to new specialists that the villages were unable to absorb, and the low birth rates suffered in modern Western societies were the main factors that provoked the economic collapse of these areas, the abandonment of places, and the maladministration of the countryside. In recent years, rural tourism, that is, city people seeking the tranquillity and simplicity of rural areas, has partly alleviated the problem of the abandonment of villages. However, in general this tourism is a very seasonal and short-term, and does not contribute at all to creating new economic structures that foster the permanence of inhabitants in the place, hiding the real problems of rural areas: isolation (poor roads or low internet connectivity), lack of supplies and services, the ageing of the population, etc.

Despite this modern return to the "locus amoenus", the word "rural" still has a pejorative meaning, and the belief that customs and ways of life, speech, or even architecture are inferior, backward, and crude, is hard to eradicate. This fact, maintained over the centuries, has led to the destruction of part of the rural architectural heritage for the sake of misunderstood modernity.

Vernacular Architecture

The term "vernacular" is the most widespread when defining this kind of rural architecture. Its etymology alludes to what is representative of a specific place and time. Thus, it is an architecture characterized by its dependence on local needs, resources, and traditions, which makes it impossible to copy without losing its essence. It is an architecture without architects, since it has incorporated the skills and experience of local builders [1]: it is a "resilient" architecture that knew how to adapt to the different circumstances and needs that arose [2].

Vernacular architecture has been revisited in recent years by architectural specialists in search of the energy and resource efficiency it has always boasted, however, the consideration of these attributes has not always been so. As mentioned previously, in the case of Spain, the abandonment of the countryside in the mid-20th century caused many of the buildings to collapse due to a lack of use and conservation. The arrival of democracy entailed a period of economic prosperity, which brought, in turn, a change in production and consumption models, along with an increase in population. These changes meant that both the old spaces associated with agricultural and livestock farming and the dwellings near them underwent remodelling to adapt them to new production and housing needs (Figure 1), which meant their complete disappearance in most cases. Only in places where the economic boom was not enough to reactivate the population and to change the ways of life in a profound manner did the old buildings continued to survive.

Figure 1. "La bomba", in 1985 and nowadays. Old troughs and houses, Fuente del Maestre, Spain (Photo: Manuel García).

Paradoxically, the fact that some places have become stuck in the past has turned them into a tourist attraction. Consequently, in some of these villages, it has been possible to restore their most unique buildings, giving them a second lease of life and saving them from disappearance. However, this is not a widespread trend. In some areas, far from the usual tourist routes, this heritage is still being lost nowadays. This situation has led some administrations (local, regional, and national) to start adopting actions to alleviate the problem of disappearance. One of the most common resources is the creation of repositories of vernacular architecture, as is the case of the Junta de Extremadura [3]. However, this is not a guarantee of survival. Unfortunately, a comparison of the images taken at the time of cataloguing and currently reveal that a gradual and severe deterioration is occurring.

Therefore, the preservation of heritage, both cultural and natural, tangible and intangible, is an inescapable task for today's society. Heritage is the identity of peoples and preserves collective memories, helping to reinforce the idiosyncrasy of places and to lay the foundations for the future. Cultural heritage, in particular, must be a source of inspiration and social integration, and also an aid to boost the economic dynamism that increases the capacity for rural revitalisation [4].

On the path towards the total protection of heritage buildings, the use of technology has allowed specialists in conservation and preservation to develop new multidisciplinary methods that help them to improve results and optimise time [5]. Among the most widely used techniques, those related to scanning and 3D modelling, as well as the development of virtual and augmented reality applications, are the most promising [6]. These methods can be implemented to ensure the physical survival of the heritage good [7] or to keep its memory when, unfortunately, it is condemned to disappear [8]. Similarly, technology has become an essential tool when disseminating and making immovable heritage known. It can be considered as the best vehicle to connect young users with their territory and its cultural value through the daily use of mobile devices.

As known, unlike VR where the user interacts in a fully recreated world, AR is concerned with generating layers of virtual information that must be correctly aligned with the image of the real world to achieve a desired sensation. Thus, AR is situated between real and virtual environments, and is responsible for constructing and aligning objects that are integrated into a real scenario. It allows users to see the real world in real time, enhanced with virtual object information once this is coordinated correctly in order to display a coherent superposition. The application of AR aims to enhance real-site experiences through the interaction of digital contents blended with the real environment through the screen of a digital device [9]. Recent advancements in the capabilities and affordability of hand-held devices suggest that AR content has reasonable accessibility.

Accordingly, in recent years, educational facilities, such as museums and galleries, have increasingly made use of the benefits offered by AR to enhance the learning experience of visitors. Similar trends have also been observed in architectural heritage, where the idea of applying AR to its study, conservation, and dissemination has emerged strongly.

Following this line of thought, this paper analyses the use of augmented reality to help people know, understand, and value vernacular architecture. The AR experiences designed for such purposes must not only ensure the resilience of the buildings but also contribute to the socio-economic revitalisation of the places in which they are located. To this end, Section 2 begins with a bibliometric analysis addressing the scientific activity in the use of AR for the dissemination of cultural heritage, continuing with a review of the state-of-the-art practices on this topic, which includes articles from the bibliometric analysis but covers a wider spectrum of the literature in this respect to give a broader view and better contextualisation. As a result of the analysis of the literature, A decalogue of good practices on the use of AR for the dissemination of vernacular architecture as a way of reactivating the economy of rural areas is stated in Section 3. The second part of this section is dedicated to briefly presenting the procedure we followed to develop an AR application to visit an archaeological site that had to be covered to allow a road to pass

over it. Section 4 consists of a succinct discussion of the paper. Finally, some conclusions are outlined in Section 5.

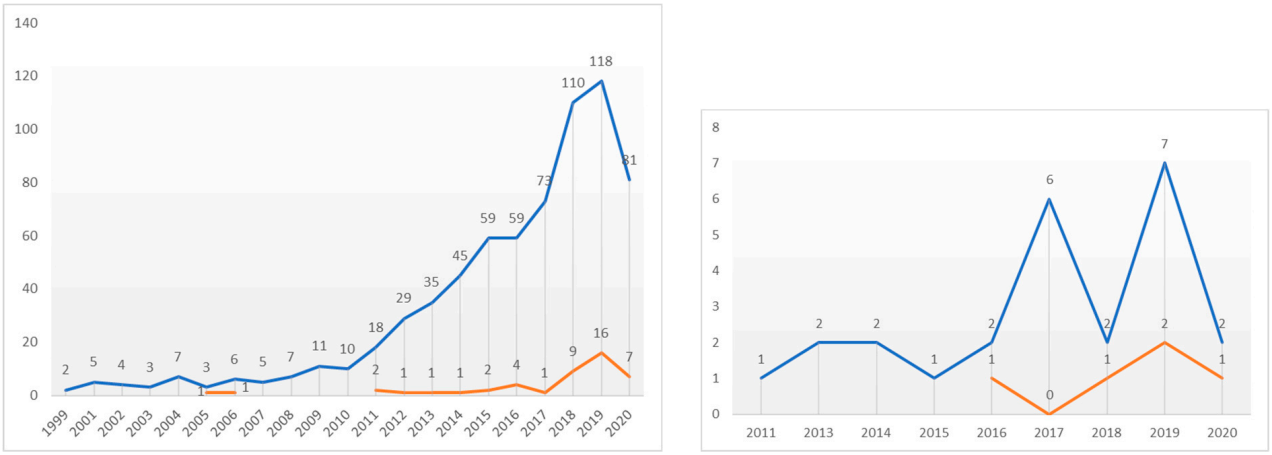
2. Materials and Methods

In order to establish a decalogue of good practices, we considered it necessary to first review the experiences published to date. The analysis of this review will allow us to reach a series of conclusions from which to draw the decalogue.

2.1. Bibliometric Analysis

As said, with the aim of analysing and studying scientific activity in the use of AR for the dissemination of cultural heritage, we have carried out a bibliometric analysis on the Scopus database. To retrieve data, we performed the following queries (on 17 December 2020): topic = (TITLE-ABS-KEY ("augmented reality" AND "cultural heritage")); topic = (TITLE-ABS-KEY ("augmented reality" AND "cultural heritage" AND "dissemination")); topic = (TITLE-ABS-KEY ("augmented reality" AND "architectural heritage")); topic = (TITLE-ABS-KEY ("augmented reality" AND "architectural heritage" AND "dissemination")).

The total number of documents found for the first query (relating to "augmented reality" with "cultural heritage") was 693. This number was reduced to 46 when the term "dissemination" was added. There were only 25 documents for the query with "architectural heritage" and this number dropped to 5 when "dissemination" was added to the search. Figure 2 shows two plots with the number of documents sorted by year. The first aspect to highlight is that this is a relatively recent field of research (the first document appears in 1999), in which activity has clearly increased in recent years, reaching a peak in 2019 with a total of 118 papers for "cultural heritage". When the term "dissemination" is added to the search, the maximum value also happens in the same year. Besides, it can be seen that the first works that relate to both concepts are not published until 2005. Later still does the association between "augmented reality" and "architectural heritage" occur, and it is not until very recently that the "augmented reality" was used for the dissemination of architectural heritage, as seen in Figure 2b.



(**a**) (**b**)

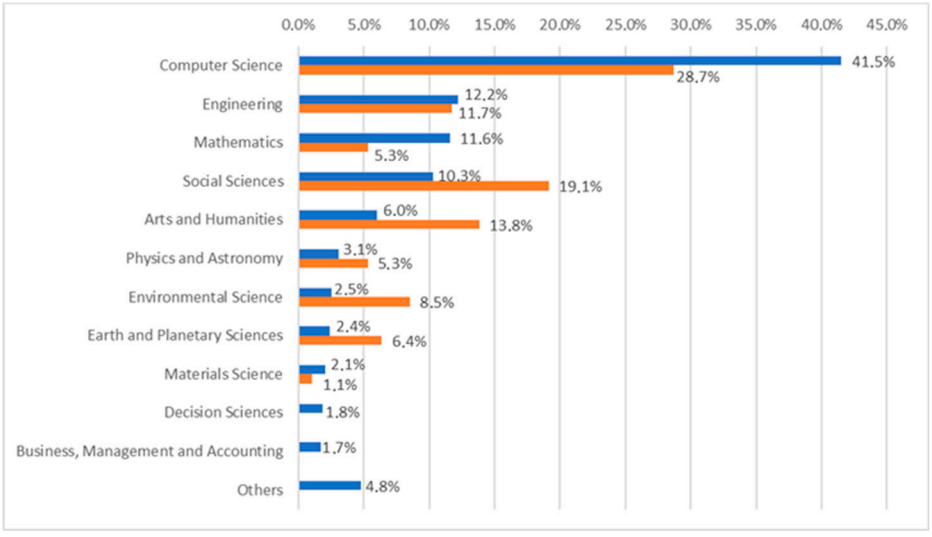
Figure 2. Life cycle of the publications relating "augmented reality" with (**a**) "cultural heritage" (in blue) and "dissemination" (in orange); (**b**) "architectural heritage" (in blue) and "dissemination" (in orange).

Table 1 shows the type of document for each query in percentages. In all cases the largest number of documents corresponds to publications at conferences, except for documents dealing with augmented reality applied to the dissemination of architectural heritage.

Table 1. Type of documents (%).

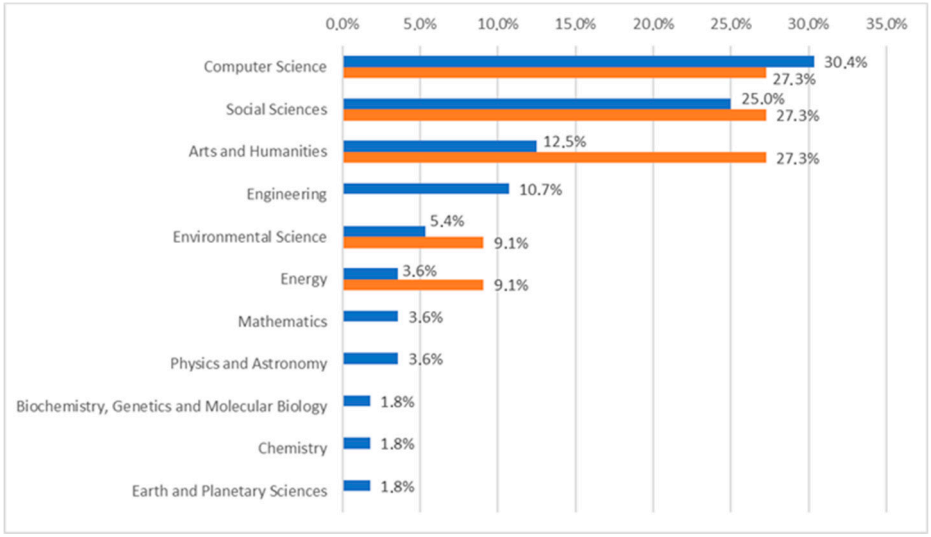
Doc. Type	Cultural Heritage	Cultural Heritage Dissemination	Architectural Heritage	Architectural Heritage Dissemination
Conference Paper	63.6	50.0	52	20
Article	24.3	39.1	36	80
Conference Review	5.4	2.2	4	-
Book Chapter	4.3	4.3	4	-
Review	1.6	2.2	4	-
Book	0.3	2.2	-	-
Editorial	0.3	-	-	-
Letter	0.1	-	-	-

When analysing the number of documents per subject area, it is worth pointing out that the contributions from the fields of computer sciences, engineering, and mathematics are the most numerous for "cultural heritage". In the query concerning "cultural heritage" and "dissemination", the first field is still computer sciences, but social science and arts and humanities become the second and third most important fields. These three fields are also the first when searches incorporate the terms "architectural heritage", and "architectural heritage " and "dissemination" (Figure 3).



(**a**)

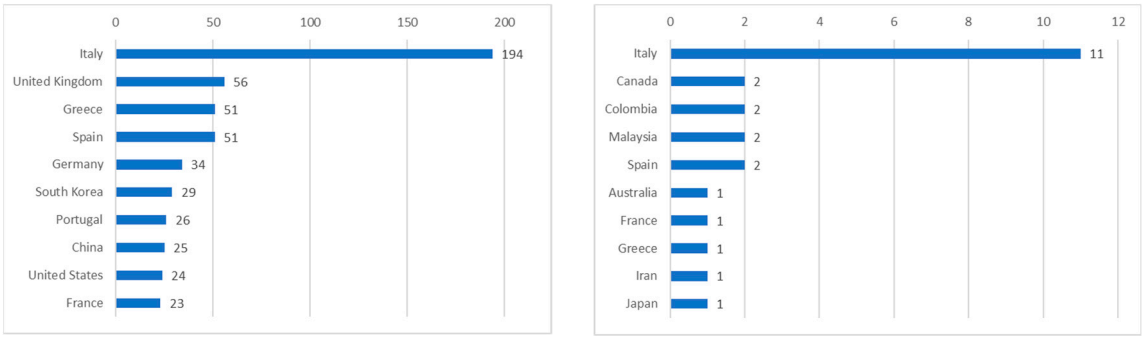
Figure 3. *Cont.*



(**b**)

Figure 3. Subjects of the publications relating "augmented reality" with (**a**) "cultural heritage" (in blue) and "dissemination" (in orange); (**b**) "architectural heritage" (in blue) and "dissemination" (in orange).

Finally, as shown in Figure 4, it is interesting to note that most of the production is European, with Italy clearly at the top of all the queries made in the database. It is also important to highlight the third position of Spain, along with Greece, in the queries concerning "cultural heritage" and the second position of Spain, together with Canada, Colombia, and Malaysia, for the queries concerning "architectural heritage", which gives an idea of the level of interest in these fields that exists in the authors' country.



(**a**) (**b**)

Figure 4. Top ten countries of the authors of the publications relating "augmented reality" with (**a**) "cultural heritage" and (**b**) "architectural heritage".

2.2. Augmented Reality for Cultural Heritage Dissemination: A Review

After the bibliometric analysis of the publications in the field was completed, we reviewed their content with the idea of identifying features that AR applications must have to fulfil the objective of disseminating cultural heritage.

This review of the wider spectrum of publications (the one that relates "augmented reality" with "cultural heritage") reveals two trends in terms of the applicability of AR to this field. On the one hand, the older theories, which are more limited since the possibilities of the technology were not fully developed, consider these types of experiences in terms of their use either as guides to visit museums and historical sites or for a better

appreciation/knowledge of a work of art as, for instance, in [10–15]. The use of AR to guide visits to cultural heritage sites is still in use today, as can be seen in S11, S18, S19 (listed in Table 2), since AR has demonstrated itself to be a good resource for improving the visitor experience in museums and historical sites.

Table 2. Documents selected from the query "augmented reality" and "architectural heritage".

Paper	Reference
S1 [16]	Calisi et al., Architectural historical heritage: A tridimensional multilayered cataloguing method. IISPRS Archives, 2011, 38 (5W16), pp. 599–606.
S2 [17]	Meschini et al., Disclosing Documentary Archives: AR interfaces to recall missing urban scenery. Proceedings of the DigitalHeritage 2013, 2, art. no. 6744783, pp. 371–374.
S3 [18]	Durand et al., Ray-on, an on-site photometric augmented reality device. Journal on Computing and Cultural Heritage, 2014, 7 (2), art. no. 7.
S4 [19]	Rossi et al., A framework to increase the video-mapping accuracy of an architectural heritage mock-up. ACM International Conference Proceeding Series, 2014 April, art. no. a3.
S5 [20]	Cordido et al., The altarpieces of de la Candelaria in Guarenas and del Rosario Chapels in San Jacinto de Caracas Church: A graphic method to establish their historic relation, 2016, Revista 180, 38.
S6 [21]	Cárdenas, M.I.Z., Augmented reality application for the dissemination of cultural heritage [Aplicación en realidad aumentada para divulgación del patrimonio cultural]. Kepes, 2016, 13 (14), pp. 33–59.
S7 [22]	Azmin et al., Architectural heritage restoration of Rumah Datuk Setia via mobile augmented reality restoration. Planning Malaysia, 2017, 15 (1), pp. 139–150.
S8 [23]	Petrucci et al., Musepick: An integrated technological framework to present the complex of Santissima Annunziata in Ascoli Piceno (Italy). ISPRS Archives, 2017, 42 (5W1), pp. 557–564.
S9 [24]	Albourae et al., Architectural heritage visualization using interactive technologies. ISPRS Archives, 2017, 42 (2W5), pp. 7–13.
S10 [25]	Ioannidi et al., Flaneur: Augmented exploration of the architectural urbanscape. Proceedings—IEEE Symposium on Computers and Communications, 2017, art. no. 8024582, pp. 529–533.
S11 [26]	Morganti et al., Habanapp: Havana's architectural Heritage a click away. ISPRS Archives, 2018, 42 (2), pp. 723–730.
S12 [27]	Banfi et al., Extended reality and informative models for architectural heritage: From scan-to-bim process to virtual and augmented reality. Virtual Archaeology Review, 2019, 10 (21), pp. 14–30.
S13 [28]	Germanese et al., Architectural heritage: 3D documentation and structural monitoring using UAV. CEUR Workshop Proceedings, 2019, 2320, pp. 1–12.
S14 [29]	Shabalina et al., Investigating regional heritage through the development and playing of AR games. Proceedings of the European Conference on Games-based Learning, 2019 October, pp. 631–638.
S15 [30]	Luigini et al., 3D digital models for a widespread museum: The Renon's "Bauernhöfe", ISPRS Annals of the Photogrammetry, Remote Sensing, and Spatial Information Sciences, 2019, 42 (2/W9), pp. 447–453.
S16 [31]	Matini et al., A 3D approach to reconstitution of the adobe citadel of Bam after earthquake. International Journal of Architectural Heritage, 2019, 13 (4), pp. 600–618.
S17 [32]	Rashid et al., Geospatial platforms and immersive tools for social cohesion: The 4D narrative of architecture of Australia's Afghan cameleers. Virtual Archaeology Review, 2020, 11 (22), pp. 74–84.
S18 [33]	Li et al., Development of an augmented reality application for protecting the perspectives and views of architectural heritages. IEEE International Conference on Consumer Electronics—Taiwan, ICCE Taiwan 2020, art. no. 9258299.
S19 [34]	Lin et al., In-depth learning of architectural heritage with application of augmented reality based on sequential scenes. IEEE International Conference on Consumer Electronics—Taiwan, ICCE Taiwan 2020, art. no. 9258120.
S20 [35]	Templin et al., The use of low-cost unmanned aerial vehicles in the process of building models for cultural tourism, 3D web and augmented/mixed reality applications. Sensors (Switzerland), 2020, 20 (19), art. no. 5457, pp. 1–26.

On the other hand, the latest studies contain up to five diversifications of the possible uses of AR for cultural heritage, including uses that are shared with other immersive technologies (virtual reality and mixed reality). These five categories are education, exhibition improvement, exploration, reconstruction, and virtual museums, and were systematised in [6]. Obviously, the previous trend is included within this one, but now from a broader and more enriching perspective.

In accordance with the concept of this work, focusing on architecture within the broad concept of cultural heritage, we have elaborated Table 2 with the resulting documents for the query "augmented reality" and "architectural heritage". Not all 25 documents are listed because some of them were compilations or reviews and so the analysis to extract the information summarized in Table 3 was not applicable to them. Thus, Table 3 identifies the categories mentioned in the previous paragraph in which each of these documents can be included.

Table 3. Identification of the categories in which the papers in Table 2 can be included.

Reference	Guide	Work of Art	Exhibition	Education	Reconstruction	Virtual Museum
S1	×	×	×	√	√	√
S2	×	×	×	×	√	×
S3	×	×	×	×	√	×
S4	×	×	√	√	×	×
S5	×	√	×	×	√	×
S6	×	×	×	√	√	×
S7	×	×	×	×	√	×
S8	×	×	×	×	√	√
S9	×	×	×	×	√	√
S10	√	×	×	√	×	×
S11	√	×	×	×	×	×
S12	√	×	√	×	√	×
S13	×	×	×	×	√	×
S14	×	×	×	√	√	×
S15	×	×	×	√	√	√
S16	×	×	×	×	√	√
S17	√	×	√	√	√	√
S18	√	×	×	×	×	×
S19	√	×	×	×	×	×
S20	√	×	√	×	×	√

In the following lines, the main aspects to consider when designing an AR experience, that is, "how" (technological aspects) and "for what" (application), will be examined through a reflective revision of the bibliography on the theme.

To begin with, there are several technology-related issues that need to be solved. Needless to say, the better the nature of their resolution, the better the experiences offered will be. This is especially true for applications dealing with complex and unstructured environments such as archaeological sites. Therefore, the proposal of new methods that solve some of the technological problems existing today will improve both AR systems in general and the outcome of any given situation in particular. This is hence an open field for researchers. Among the technological aspects that can be addressed [6], the most interesting are:

- The modelling of virtual environments;
- The tracking the location of users;
- The 3D registration of real images with virtual models.

As far as 3D modelling is concerned, different techniques can be used depending on the objective of the application being developed. In the simplest cases, the use of 3D design software which allows the creation of artificial virtual models, such as 3DS Max or Blender, suffices. When the application to be performed involves the reconstruction of heritage assets, it is necessary to use other tools to generate 3D models from the real data. The most common techniques used to acquire 3D data are photogrammetry (SfM) [36] and 3D laser scanners [37]. In this case, a new problem must be faced: the adaptation of these 3D models for real-time visualisation. Some proposals regarding resolving this problem have been published recently, although it is not yet totally solved. Undoubtedly, this is an important issue whose resolution will improve the quality of AR applications in the field of cultural heritage [38].

Tracking the location of users allows one to know where they are. The 3D registration determines the users' points of view in order display on the devices used for this purpose the virtual models superimposed on the actual heritage pieces. It is also responsible for modifying the orientation and scale of the virtual models so that they are correctly seen on the real image. Both problems, tracking and registration, are related to each other and are solved by combining information from different sensors in most cases: GPS, inertial measurement units (IMU), and cameras. The information provided by the two first types of sensors is usually utilised to track the location. Meanwhile, the information obtained from the application of computer vision algorithms on the images captured by the cameras is commonly used to locate the users, although it can also be used to solve registration problems. In the case of AR applications in outdoor heritage sites, GPS or IMUs, along with cameras, are the most used sensors. For indoor heritage sites, a camera alone is usually used to locate the user and to solve the registration problem through mark recognition [39,40]. Even so, the problem of real-time registration is still an open issue only solved for the simplest geometric shapes. Obtaining the same real-time results for free-forms and organic objects as those of cultural heritage is far from achieved. In AR applications, it is essential to avoid latency, since the delay makes the experience unsatisfactory for users, despite the perfect technical results.

When designing any system or software that involves a non-expert user, it is very important to follow user-centred design (UCD) processes [41,42]. This is particularly important in the cases discussed in this paper, as the applications designed are intended to be used by a wide range of people. In other words, in general, it must be assumed that most users have no previous technical (mobile and AR) or historical knowledge. A wide variety of tools and methodologies for research, design, rapid prototyping, and user testing of mobile AR user experiences can be found in the literature (e.g., [43]).

Apart from the interface, within the design process both the amount and the flow of information the user should receive has to be decided. It is obvious that too much information could overwhelm the user. In this sense, three parameters can be considered when designing AR and VR applications: presence, affordance, and usability.

Presence is usually defined as "the degree to which a user feels like they are in reality while experiencing the extended reality". In Barfield's study [44], some parameters for measuring presence are provided. An example can be found in [45], where it is reported that some users "lose sight of where the game ends and reality begins". Therefore, in an application, the higher the level of presence, the better the result of the impact and assimilation of the information in the user. Of course, it is very difficult to quantify this, and no generalizations can be made.

Another concept to consider is affordance, which can be defined as "a factor inducing an action for a user to accurately recognize and operate the meaning of an object of interaction in an augmented reality environment". To measure this parameter, some items can be extracted from Harton's classification of the types of affordance [46].

Finally, the concept of usability is also essential, redefined as "the degrees of effectiveness, efficiency, and satisfaction for a user completing a task in a augmented reality environment" in [47]. The studies of Anderson and Shapiro [48], Nielsen [49], and Dünser [50], provide very valuable experience in the evaluation of usability.

As for the works in Table 2, most of them neither explicitly mention nor explain any aspect related to the presence, affordance, or usability of the application they develop. Some of them do highlight the ease of use, given their orientation to the general public attending museums or visiting historical buildings. Only in S6 are both presence and usability are analysed, and in S10 just usability. S20 highlights the increase in presence due to the use of augmented reality devices. On the contrary, in S7 they refer to the poor visualization and the delay offered by the augmented reality experience presented.

2.3. Augmented Reality for Cultural Heritage Enhancement

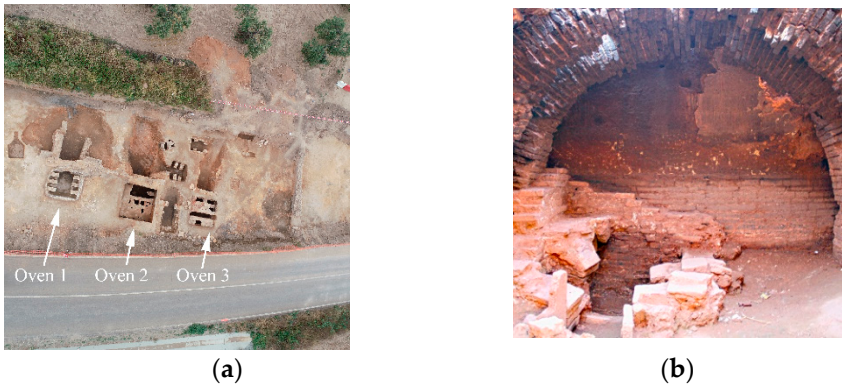
As previously mentioned, one of the applications of AR in cultural heritage should be facilitating the research of archaeologists, historians, and conservation experts. However, history is a quite immovable field of knowledge since these specialists are usually reluctant to abandon old methods. This could be the reason why it is very difficult to introduce the innovations that technology provides to enhance the investigations in these areas. Even so, some new initiatives have appeared in the last decade, which mean a big leap forward with regards to the previous way of working. Unfortunately, in the case of AR, literature focused on this topic is quite rare [51]. Experts have always considered it as a means of entertainment and enjoyment and a way of enabling people to approach cultural heritage. Thus, needs surrounding the use of AR as a tool for research have not been consolidated yet.

The other two aspects to be taken into consideration when talking about cultural heritage are education and dissemination, which are connected. In this case, education plus dissemination means preservation. There is no better way to preserve a heritage building than to know it, appreciate it, and put it to good use.

One of the most common applications of AR systems, and one of the oldest, is the facilitation and improvement of user experiences IN interpretation/visitor centres and museums. This is usually done by adding signs in real images, which, for example, may indicate the itinerary of the exhibition or show extended information about pieces on display [52,53]. Another digital advance, based on the high-end rendering capabilities of game engines and the AR applicability, is the development of animated pedagogical agents which play the role of guides or educators to guide visitors and explain the exhibitions [54]. Other relational agents can be found in Traum et al. [55]; Lane et al. [56]; or Vosinakis and Avradinis [57].

It is also worth mentioning the use of AR to show reconstructions of cultural heritage assets that cannot be visualised because they have completely disappeared (Figure 5) or to display the missing parts of buildings in ruins. In the latter case, AR allows the visual integration of the reconstructed/modelled parts with the real ruins that still exist [58–60].

The last point to mention is the use of AR to create "serious games". This type of game is designed for educational purposes with the aim of supporting players to accomplish learning objectives in a fun way [61]. To date, these games are mainly focused on formal education. However, informal educational settings can also benefit from "serious games". When used for the dissemination of cultural heritage, they are a perfect way to attract new types of visitor, such as children and teenagers [62].



(**a**) (**b**)

Figure 5. Photos of the archaeological site "La Matilla": (**a**) aerial view of the exterior area; (**b**) interior of one of the three ovens located at the site.

3. Results

As already mentioned, cultural heritage assets in general, and vernacular architecture in particular, help to generate identity, values, and culture, propitiate cohesion, and even to support community experiences. The importance of this sort of architecture goes beyond this, as it can also be the focus of a tourist attraction, becoming an economic engine in many previously depressed areas. Moreover, experts from the public and private sectors consider it a driver for local development, as it is a powerful source of income. This change of approach to the value of vernacular architecture, from considering its conservation and maintenance as a burden to understanding it as an important asset in society, must be carried out together with educational actions and successful practices. However, sometimes it is not easy to persuade certain types of people to invest in technological proposals, as is the case with AR experiences, over others that are considered a priority. All initiatives undertaken must be supported by empirical evidence and practical demonstration of their impact on the economic, cultural, and social improvement of the surrounding area. This can only be achieved through intelligent management [4].

Therefore, any proposal related to obtaining economic and social benefits from the vernacular architecture assets should not be made without taking into account the inhabitants of the area. They are the "owners", and they should be the only beneficiaries. In this case, they need to be convinced that the medium-term benefit is great. To this end, it is equally important that they are engaged and committed in the creation of the AR experience.

The economic viability of this type of project is reinforced by the possibility of AR to be run on visitors' mobile devices (smartphones and tablets). This makes the investment in inventory material and maintenance quite low. Most of the funding may be used for data acquisition, design, and implementation of the AR application. In the documentation phase, it is essential to count on the collaboration of the inhabitants, so that they feel involved in the project and can contribute their knowledge about the buildings and their ideas to improve the AR application. One of the disadvantages we could face when implementing an experience like this is the lack of internet connectivity that some rural areas suffer from. Proposing an eye-catching experience for the authorities could encourage investment in this sense. The capacity to involve stakeholders who sponsor this type of project would also be another factor in achieving its viability.

Bearing in mind the people at whom this type of initiative is targeted, we must also consider a number of determining factors: the experiences must have the capacity to attract a wide and varied audience, from the elderly to families with young children and from the inhabitants of the surrounding areas to specialists in any of the subjects involved in creating them. Likewise, they must create in users the desire to visit the location and stay to continue seeing and knowing it.

The initiative can be considered a success if, on the one hand, it serves as a tourist attraction and, on the other hand, it provides stable economic benefits to the community

concerned, either indirectly (trade, hotel nights, etc.) or with the creation of jobs associated with its implementation.

3.1. Decalogue of Good Practices

Although some books, papers, and documents on best practices for the intelligent management and dissemination of cultural heritage assets in general and historical buildings in particular have been published recently [63], they are manuals mainly inspired by the progress of cities and urban architecture [64–66]. To the best of our knowledge there is nothing specifically focused on the rural environment so far.

On the basis of these manuals and the premises mentioned above, as well as on the basis of the initiatives gathered in the reviewed literature, we are in a position to outline some good practices that should inspire the creation and implementation of AR experiences that are beneficial for the socio-economic environment in which they are developed. The main factors that motivated us to compose this decalogue were the necessities for acquiring, cataloguing, and visualising historical buildings exposed in S1; the empirical experience performed in S6 that provides a summary of methodological actions in its Table no. 2; the methodology used in S7 to systematise the five steps to follow (presented in the flow diagram in its Figure 2); the solutions found in S14 from the perspective of gamification, which fosters the attraction and implication of the public with the AR application; and the idea of social cohesion worked on in S17 to engage autochthonous people and visitors with the remains and the experience.

The task that should be undertaken first and foremost is to convince both local authorities and the general population of the need to create such strategies to reach and attract different types of tourists. Once the need has been created, we consider it essential to proceed as follows:

1. Document the heritage assets under study, their state of conservation, location, accessibility, etc.
2. Make a socio-economic study of the town and its surroundings, communication routes and connectivity.
3. Evaluate tourist flows, typology, tastes, seasonality, etc.
4. Study the economic viability of the proposal, assessing both the costs of staff, material, equipment, maintenance, etc., and the direct and indirect benefits.
5. Look for investors, both public and private, to finance the project.

Once the previous points have been acknowledged, in terms of the creation and implementation of the AR experience, these five practices are considered the best:

6. Technology must be used as a means, not as an aim. It is used to improve the knowing, learning, and enjoyment of the building.
7. Internet connectivity must always be available and the necessary facilities for the normal development of the experience assured.
8. The AR application has to be free for visitors, easy-to-use, and able to run on any average device. When designing the experience, ensure the desired levels of presence, affordance, and usability. Improvements, updates, further developments, etc., must be guaranteed for two years after the start of the experience.
9. The information provided by the AR experience must be easily understandable. At the same time, it should create the expectation for the user that they will continue to learn more about the surroundings.
10. The implementation of the AR experience must be complemented with a good communication strategy through social networks, institutional announcements, presentations at fairs, conferences, etc., to reach the largest possible audience.

3.2. An Example: AR Application of the Archaeological Site "La Matilla"

We are developing an AR application for the dissemination of cultural heritage in a particular case in which the site is no longer accessible. Specifically, the application is intended for the visualization of some archaeological remains of Roman buildings and

ovens that were found by chance during refurbishment works of the road EX-360, near the town of Fuente del Maestre (Badajoz, Spain), at the place known as "La Matilla". Some photos of the site can be seen in Figure 5. After analysing the findings, evaluating their historical value, and calculating the increase in time and cost that their conservation would entail for the road works, the authorities decided to cover them once digitized. This would at least provide the raw material to generate tools that allow people to visualize these remains later on, when already hidden, either by physical reproduction or by representation through digital technologies: screens, VR, or AR devices. Up to now, we have developed a proof of concept of an AR application to enable the visualization of the site with a mobile phone.

When we decided to design this AR application for the remains found, we took into account that although Fuente del Maestre (Badajoz) is a little town of less than 7000 inhabitants it has a very important cultural heritage. Its archaeological, historical, and monumental wealth led the Government of Extremadura to declare it an "asset of cultural interest with a historical set category" (Decree 136/1998 of 17 November). Due to this, we had at our disposal very interesting bibliography, news, and documents on the surroundings to fulfil points 2 and 3 of the decalogue. Obviously, the data acquisition of the remains and its historical and archaeological study (point 1 of the decalogue) was made before this AR application were conceived.

Concerning the point 5, the local authorities showed interest in the project and will study the budget of the initiative once this AR application became a reality. Besides, this town is home to two of the most important export companies in Spain, which employ a significant number of people and are a focus of attraction for many sales agents, workers, businessmen, politicians, etc. The implication of these private firms will be the next step.

All these advantages motivated us to undertake the design of the AR application thanks to the funding provided by the research projects in which we participate, which for now complies with the point 4 of the decalogue in this phase of "development" we are in.

In our application, technology becomes the only means to make accessible the remains that had to be buried. On the one hand, AR allows researchers to analyse this type of historical construction and, on the other hand, it gives the general public the opportunity to know and explore, above ground level, remains that are buried at a certain depth beneath their feet. This application will undoubtedly be a tool that will allow both target audiences to enjoy the building and learn about these characteristic remains (point 6 of the decalogue).

The idea is to install a fixed stand, suitably signposted, in the area where the buried remains are located. This signage would consist of a poster that would include an explanation of the process of downloading and installing the app, a user manual, and information with summary photographs of the site for users who prefer not to install the application.

Fortunately, currently, mobile internet networks have improved considerably in terms of both coverage and speed. Specifically, it has been verified that in the area where the buried archaeological site is located, internet connectivity is available (point 7 of the decalogue).

Our application is intended to be always free of charge. As mentioned above, these remains are located in a region rich in heritage and which has strong support from the authorities to promote initiatives that study, protect, and disseminate historical heritage. Therefore, it is to be expected that there will always be backup for maintenance of the application so that it is always available to visitors (point 8 of the decalogue).

To develop the proof of concept we have so far, we followed the procedure shown in Figure 6.

The 3D digitization process consisted of the combination of three different technologies: laser scanning, structured light scanning, and digital photography. Since each of them produces data with different resolutions, we decided the following strategy to concurrently apply them in the way that was fastest and most optimal:

- The laser scanner was employed to digitize the exterior area of the site, producing 3D high resolution coloured point clouds.

- The structured light (handheld) scanner was used to acquire the interior of the three ovens, producing 3D high resolution textured meshes.
- The digital camera was utilized to take hundreds of photos of both the exterior area of the site and the interior of the ovens, for later use in photogrammetry software. After the computation, 3D low resolution textured meshes were generated.

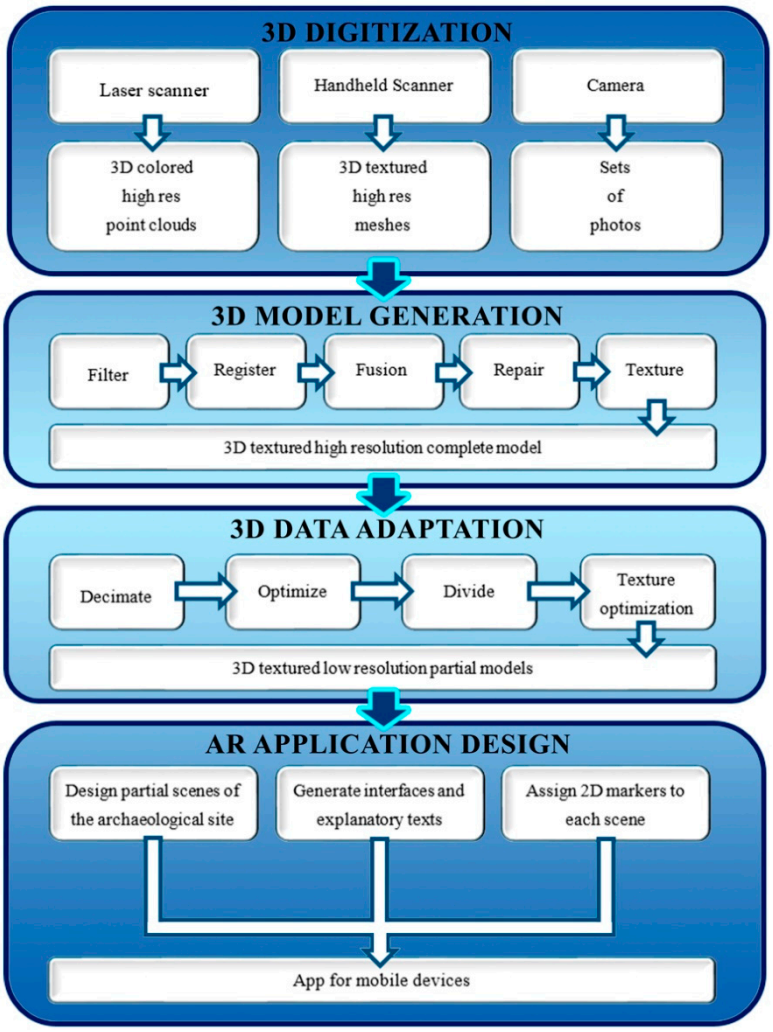


Figure 6. Scheme of the procedure to produce the proof of concept of the AR application.

Then, the next stage in the procedure is the processing of all the data obtained separately from each capturing technology to generate the 3D model of the site. We can summarize this step by enumerating and briefly describing the sequence of tasks that compose this process:

1. Filter: eliminate undesired data and errors.
2. Register: apply the appropriate transformations (position, rotation, scale) to make all the sets of 3D data accurately fit to one another.
3. Fusion: generate a unique mesh with all the information provided by the digitization technologies.
4. Repair: analyse and correct the errors of the mesh to generate a manifold mesh.
5. Texture: compose a unique texture map with optimized distribution from all the texture information generated by the different digitization technologies used.

At this point, we have a digital, accurate 3D model, useful in a great variety of applications. Regarding the application of AR, since it is intended to run on mobile devices,

both the resolution of the 3D mesh and the texture must be reduced. This leads to a third stage in our procedure: 3D data adaptation. It consists of the following tasks that provide the results shortly described below:

1. Decimate: drastically reduce the number of points of the mesh.
2. Optimize: slight reduction of the number of points optimizing their distribution, concentrating the points where curvature is greater.
3. Divide: split the mesh into smaller parts to be visualized in different scenes of the AR application. The reason for doing this is due to the technological limitations of mobile devices when representing big 3D objects. This task is related to both the decimation and optimization performed in the previous tasks.
4. Texture optimization: To alleviate the processing of 3D data visualization in mobile devices it is also important to compose the texture map in the most optimal way.

After this stage, the 3D data are prepared to be integrated in the AR application. Finally, the application itself is implemented. A simple way to explain its development process is by dividing it into the following tasks:

1. Design partial scenes of the archaeological site. In our case, we had five 3D-optimized models as a result of the previous stage: two corresponding to the external area and three corresponding to each of the ovens. These models are now enhanced by adding ornamental 3D models or by including background sounds, resulting into five different scenes.
2. Generate interfaces and explanatory texts. It is important to design a usable application that provides the adequate material to help people improve their knowledge, learn, and enjoy, and that generates the need for further information about the site. Interfaces must be intuitive since it will be used by a very diverse group of people (points 8 and 9 of the decalogue).
3. Assign 2D markers. One of the methods currently available to launch the 3D representations in the AR applications is the use of 2D markers. These markers are basically 2D images which are recognized by the application to begin the visualization of a 3D model. In our proof of concept, we assigned one image with a text for each of the 3D models. Figure 7 depicts two of the markers.
4. Generate the application for the mobile devices. Since we have used Unity software to create the AR application, it is relatively easy to reorient the developed content to be compiled for different types of hardware. So far, we have only generated an application for Android mobiles.

Figure 7. Two of the markers designed to be used in the AR application.

Figure 8 shows some images of the use of our AR application and a view of the interior of one of the ovens that can be visited in the experience.

(**a**) (**b**)

(**c**)

Figure 8. Two moments of the use of our AR app: (**a**) the user focuses the camera on the marker; (**b**) the 3D model of the site is shown over the image of the marker; (**c**) the 3D model of one of the ovens displayed in the AR application.

Regarding the level of presence (point 8 of the decalogue), it is undeniable that AR applications for cell phones do not offer a presence comparable to the immersion offered by a VR equipment. In any case, although the 3D scenarios have had to be optimized for mobile devices, the quality of the textures produces a very realistic effect in the visualization of the site, which definitely contributes to increasing the level of presence in the experience.

Since the application is still in the prototype phase, it has not yet been disseminated in conferences, social networks, or through institutional announcements (point 10 of the decalogue). This is an issue that is considered of great relevance in order to achieve the application's own objective: raise awareness of the remains, particularly in the case where people may not know of their existence, and, at the same time, make these people participants in the revolution that the application of technologies for the dissemination of heritage, the learning about history, and the digital preservation of valuable remains that have survived the passage of time entails. In the medium term, we plan to first launch a local information campaign among the inhabitants of the site's surroundings and then to extend this campaign to the whole region.

4. Discussion

Throughout these pages, we have discussed about the problem of "empty Spain", the causes of the depopulation, and the consequences this fact has at present. Despite this, these empty areas have a rich architectural heritage of traditional buildings. This vernacular architecture, which we have also defined in this paper, can be one of the main economic resources for the places where they are located, provided that the necessary strategies are developed for its conservation, enhancement, and dissemination. However, it is not always easy for local authorities to undertake this task.

Technology has come to alleviate some of these problems by facilitating the work of heritage experts. By the same token, technology can also be an economic driver for these depressed regions to regain their vitality.

Among other alternatives currently available, AR can be used as a tool for the communication and dissemination of content, as it is attractive and differentiated from other technologies and tools from the outset. The fact that the devices for its visualization have become simpler, cheaper, and more generalized makes it a different bet, especially suitable for young audiences and consumers of technology.

A review of the literature has revealed an increasingly frequent use of AR and its potential for the knowledge and dissemination of immovable cultural heritage. It is worth noting that the first papers published along these lines belonged to the field of computer sciences, but there are increasingly more articles from the social sciences and arts and humanities, which proves that these disciplines are also adding to the same trend. In the latest years, the uses of AR for the dissemination of cultural heritage have branched out to include education, exhibition improvement, exploration, reconstruction, and virtual museums.

Based on the revisions made, as well as on the analysis of the experiences related to the correct management of heritage, a decalogue of good practices has been drawn up in this paper. We believe that this decalogue should be followed when designing projects for the dissemination of architectural heritage that include these types of experiences and when planning recovery strategies in rural areas to ensure their success. In these cases, more than in any other, the scientific and technological components of an AR experience are subjects to social and economic aspects. It is about revitalizing these rural areas and attracting and establishing a young population through new initiatives that promote new possibilities for work and social wellbeing.

5. Conclusions

AR is becoming a very relevant tool in the dissemination of cultural heritage which, if used properly, can also help the development of rural areas and the maintenance of their vernacular architecture.

In this work we have presented a bibliometric analysis of the publications made in this field in recent years and an in-depth review of the literature. This revision allows us to conclude that, although it is clear that AR is a powerful tool for the dissemination of vernacular architecture, there are still no guidelines that define how to proceed when developing an AR application for this purpose. To fill this gap, this work proposes a decalogue of good practices that should inspire the creation of AR experiences to be beneficial for the socioeconomic environment in which they are developed. Points 1 to 5 of the decalogue are to be undertaken prior to the development of the AR application, and are dedicated to the documentation of the remains and the study of economic factors and tourism feasibility. The other five points (6 to 10) focus on the implementation of the application itself.

As an example, a proof of concept of an AR application for the visualization of the archaeological site "La Matilla" is described. The site was buried to continue the roadworks that led to its discovery, and currently the only evidence of its existence that survives are the 3D models generated by the authors of this document. These 3D models have been used to develop the proof of concept.

Author Contributions: Conceptualization, M.J.M. and P.M.; methodology, P.M. and M.J.M.; software, E.P.; validation, E.P.; investigation, M.J.M.; writing—original draft preparation, M.J.M. and E.P.; writing—review and editing, P.M.; visualization, E.P.; supervision, M.J.M. and P.M.; project administration, P.M.; funding acquisition, P.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Ministry of Science, Innovation and Universities of Spain, through the project "3D massive data processing. Segmentation, recognition and geometric modelling of non-conventional buildings", PID2019-108271RB-C32.

Conflicts of Interest: The authors declare no conflict of interest.

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