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VIRTUAL MODELS FOR ARCHAEOLOGICAL RESEARCH AND 2.0 DISSEMINATION: THE EARLY MEDIEVAL CHURCH OF SAN CEBRIÁN DE MAZOTE (SPAIN)

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Abstract

Digital technology for 3D survey and virtual modeling of historical buildings has been largely improved in the last years. However, virtual reconstructions of lost buildings still offer hermetic interpretations, so that it is almost impossible to understand them critically. Such models usually avoid the diachronic perspective that is closely related to the evolutionary and complex essence of historical constructions. The present paper addresses the innovative case study of the Early Medieval monastic church of San Cebrián de Mazote (Valladolid, Spain), which has been analised to know the original building and its later additions and restorations. Besides that, this paper proposes theoretical guidelines to develop current digital 3D models of historical buildings into advanced ones by means of implementing their transformation sequence and complex essence (metadata), as well as the interpretation process that has been taken during the research (paradata).

Keywords

3D Model, Graphic Documentation, Archaeology of Architecture, Metadata, Paradata.

1. *Introduction*

Digital technology for 3D survey and modelling of historical buildings has been largely improved in the last years. The most important improvements are related to the optimization in terms of cost and versatility of survey devices and modelling applications. 3D models of historical buildings are thus nowadays more realistic, accurate and rigorous. Which one are then the main issues to be faced in order to develop advanced 3D models?

The present paper intends to address this question by showing a specific case study: the monastic church of San Cebrián de Mazote (Valladolid, Spain), a National Heritage Monument thought to have been built between the late 9th and early 10th centuries, which was however largely modified and restored all throughout its history until nowadays. Its photogrammetric survey, 3D modelling (Fig. 1) and interdisciplinary study (by applying mainly archaeological and geological analyses) are part of a research project funded by the Spanish Ministry of Economy and Competitiveness (MINECO, 2013-15) and helped by the regional government of Castilla y León (Studies and Planning Service, 2015). This work has made possible to approach the form and construction process of the original early medieval building and to identify its later additions and restorations, which all together explain the form and state of preservation of the current church.

Fig. 1: 3D model obtained using digital photogrammetry

The aim of this paper is thus to present the main outputs of the research undertaken in Mazote, as well as to provide a case study for a 3D-model-based innovative concept of dissemination, which intends to incorporate concepts such as the evolving nature of historical architecture, its context, or even the accessibility and transparency of the research process.

2. *Theoretical approach*

2.1 Understanding the evolution of society

One of the main scopes of analysing historical architecture is not only to know the building itself, but also to understand the societies that created it, lived in it and used it. Research aims so to understand the context, that is, the society, technology, economy, politic, or even the philosophy behind the built product, by analysing this accurately. Every construction is thus the result of successive contexts featured by different technologies, economies…, which have left its prints on its materiality. Traditional periods (Classical, Medieval, Modern…), coined mainly according to stylistic features, are then to be substituted by production contexts. The conceptual change here proposed aims besides to focus the research on the transformation and evolution that has been continuously developed during such historical periods.

The evolution of the society is therefore closely linked with the transformation of buildings and urban spaces, since historical architecture is thought to be not a single monument or work of art, but a manufactured product made by a specific society and related to its context. Such enlightening approach offers the opportunity to discover the population's evolution by means of the historical building's transformation. That is why it is worthy to highlight the complex essence of historical constructions.

2.2 The complex essence of the historical architecture

In fact, one of the distinctive features of historical buildings is their complexity, due to the relationship between several contexts and the connections with other buildings and urban spaces, so that a fundamental transversal nature underlies its essence. Constructions have also an evolutionary and multi-stratified essence, because they are the result of a long process of successive transformations (constructions, destructions and restorations) which have taken place throughout its history. Beyond the traditional concept of model building, which is supposed to have been built in a precise moment and it is therefore artistically catalogued within a unique period (e.g. "the Romanesque church"), the real building concept provides a ground-breaking vision based on its transformation sequence, recognizing the different buildings (or uncomplete models) comprised within one single structure (Caballero, 2009, p. 12). Thanks to the so-called method of the Archaeology of Architecture, the construction is approached like an excavated site, being so possible to elucidate the sequence of its transformations, to understand the societies responsible for these and to comprehend the mentioned real structure (Caballero, 2010).

2.3 Transparency and accessibility of digital 3D models

Taking into account the abovementioned relevance that historical architecture plays when understanding the social evolution, 3D models may contribute to the dissemination of scientific knowledge.

It is commonly assumed that 3D representation of buildings helps significantly to the comprehension of their spatial configuration. Furthermore, virtual reconstructions of lost or hidden architectural elements are sometimes essential to make people visualize them. However, these virtual reconstructions usually offer opaque and hermetic interpretations, and it is almost impossible for anyone, but for the author and/or researcher, to understand the outputs of the analysis undertaken and on which data such interpretations are based. It is therefore crucial to develop an open and transparent methodology in order to generate 3D models able to properly show the whole scientific research process beyond its results. It is consequently necessary to visualize the relationship between the initial data and latter hypotheses and interpretations that have been assumed. For that purpose, there must be a strong link between the physical object (existing element, building or archaeological remains) and the interpretation (virtual element and reconstruction) also linked with its contextualization, establishing meaningful narratives beyond the traditional "opaque" and "closed" current models. In this way, it is important to make visible the reliability of the interpreted models and its compliance with existing data. In fact, accessibility must not only be referred to the physical or technological ability to get and share data, but also to the opportunity to access to other data that support the results, in order to be able to understand the whole research process.

Such issue has been already addressed in several international theoretical documents, of which aim is to set the basis for a more efficient and transparent methodology for computer-based visualisation of cultural heritage objects. It is firstly to be mentioned the London Charter (Denard, 2009, p. 8), which states the need for the documentation of the process by using paradata: "Documentation of the evaluative, analytical, deductive, interpretative and creative decisions made in the course of computer-based visualisation should be disseminated in such a way that the relationship between research sources, implicit knowledge, explicit reasoning, and visualisation-based outcomes can be understood."

Within the specific frame of virtual archaeology, the so called Principles of Seville (López-Menchero & Grande, 2011) develop some recommendations regarding the issue of authenticity of 3D models: "(...) it should always be possible to distinguish what is real, genuine or authentic from what is not. In this sense, authenticity must be a permanent operational concept in any virtual archaeology project. (...) When performing virtual restorations or reconstructions, these must explicitly or through additional interpretations show the different levels of accuracy on which the restoration or reconstruction is based."

Besides these considerations, it must be also said that currently existing 3D models usually present buildings in a specific period of their history, avoiding the diachronic perspective that approaches their evolutionary comprehension and complex essence above explained. In order to improve the communication of their whole cultural value, such 3D models should address the visualisation of their transformations and evolution.

3. *The research of the church of San Cebrián de Mazote*

3.1 Methodology of Archaeology of Architecture

As mentioned before, our main scope is to understand the transformation sequence of buildings throughout their whole life story. In order to get this, we have applied the methodology of the Archaeology of Architecture for the last decade when studying historical architecture. Our team has leaded and participated in the archaeological study of more than 50 buildings in western Europe (Caballero, 2010, p. 118 with a list), including World Heritage sites such as Early medieval churches of Asturias (Spain), medieval churches sited in the St James' pilgrimage route (Spain), military buildings like the medieval Castelo dos Mouros in Sintra (Portugal), or in the review of old archaeological excavations like the Hemicycle of the Roman Forum in Orange (France) and the Torre Argentina archaeological site in Rome (Italy).

As stated before, the Archaeology of Architecture approaches the construction like an excavated site, being this broken up into stratigraphic units (singles contexts) whose relative chronological sequence can be established through the understanding of stratigraphic relationships and typological criteria. This method converts a building into a historic document that is legible by means of four main strategies (Caballero, 2010, pp. 107-115): stratigraphy to identify the successive stratigraphic units which compose an archaeological complex (site or building) and order them in a relative sequence; typology to characterize the features of those units and typifying them after that temporal sequence; written records to know likely past activities happened in the construction and its effects on it; and archaeometry to characterize and date those materials (ceramics, timber…) employed in the building, always according to its stratigraphic position in the sequence, by physical and chemical exams.

This methodological approach has significant applications beyond the research and knowledge of historical buildings. On one hand, the restoration projects are able certainly to benefit from the results obtained. For instance, the pathological analysis of cracks and distortions may be also implemented in the stratigraphic analysis, so that the evolution of the structure throughout the life story of the building may be obtained in order to evaluate the current stability conditions (an example in Cámara, 2010). On the other hand, the dissemination activities can be strongly enriched by including the complex and evolving essence of historical architecture, so that it will help the society to better know and enjoy cultural heritage.

3.2 The research project

The research project entitled "Archaeology of the Hispanic churches of the 10th century: the circulation of architectural and decorative models" was granted by the Spanish Ministry of Economy and Competiveness and developed between 2013 and 2015 under the leading of the scientific researcher María de los Ángeles Utrero Agudo. During this period, it was studied the circulation of architectural and decorative models, its introduction, keeping, alteration or copy in the architecture of the Iberian Peninsula attributed to the late 9th and early 10th centuries, this one commonly known as "Mozarabic" within traditional research (since Gómez-Moreno, 1919). According to this proposal, transmission of architectural and decorative models depends on the architectural knowledge, both theory and practice (technology), on one side, and on those media of transmission (patrons, artisans and documents) which make it possible, on the other. It is therefore that both aspects (knowledge and media) were studied in order to approach the circulation of models (Utrero, 2016a).

The analysis of the architectural knowledge was based on the archaeological, decorative, documental, geological and structural analyses of three ecclesiastical constructions, which are similar and, a priori, coetaneous (late 9th – early

Fig. 2: Orthoimages of the external façades and main inner walls

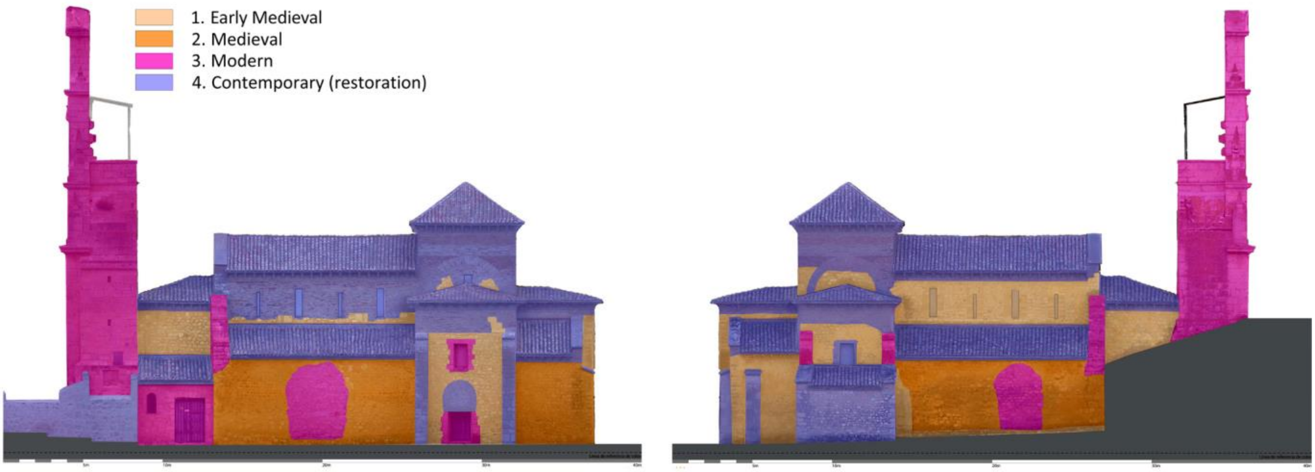

Fig. 3: Transformation sequence of northern and southern façades

10th centuries), and thus selected to be a coherent “analytical laboratory”. These are the monastic basilicas of San Miguel de Escalada (Leon) and San Cebrián de Mazote (Valladolid), in the Northern Iberian plateau, and the half rock-cut church of Las Mesas de Villaverde (Malaga), in the southern area. Related exploited quarries and sculptural materials housed in different museums were also studied with the aim of completing the knowledge of the original form on these constructions. The analysis of the media of transmission of the models was based both on the results obtained thanks to those previous analyses and on the study of related written documents (both coetaneous and later textual and epigraphic sources, both Arabic and Latin), which might contain references about them.

3.3 Main results of the research in the church of San Cebrián de Mazote

Regarding the building of San Cebrián de Mazote, the research process included the development of a 3D model (Fig. 1) as well as the elaboration of a set of orthoimages belonging to the external façades and the main inner walls (Fig. 2). To obtain such graphical documentation, a 3D survey was done by using digital photogrammetry (structure from motion) with a complete set of high resolution photographs, both terrestrial and aerial, of external and inner spaces. Thanks to the processing with a proper photogrammetric software, a dense cloud point was obtained, from which a textured mesh model has been later extracted. Finally, planar projections of external façades and inner walls were obtained from such 3D model.

The study included as well the stratigraphic analysis of the standing structures, in order to distinguish the original Early medieval (or “Mozarabic”) parts from the latter additions and transformations. Although this is still a work-in-progress research, some provisional results are shown here.

According to its archaeological analysis, the church of Mazote is roughly composed by four main phases (Fig. 3 and 4). Results firstly reject that a previous 7th-century Visigothic church could have been reused and modified by a later one (proposal defended by Corzo, 2002, p. 87). The original church dates to the late 9th and early

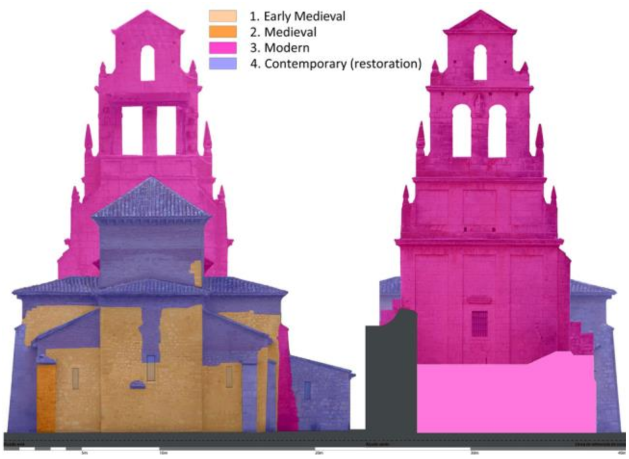

Fig. 4: Transformation sequence of eastern and western

10th centuries, being then shortly abandoned according to the written records. This church was projected and erected as a three aisled basilica with a projecting transept, a counter-apse and a tripartite chancel. New local limestone was employed to stand up the walls and vaults, of which the nearby quarries were found thanks to the geological fieldwork and petrographic exams; whereas reused material was used to erect the supports of the arcades (bases, shafts and capitals), coming these probably from a commercial activity (Utrero, 2016b). Later destructions and restorations largely modified Mazote. Only part of the chancel (northern and central apses), the internal arcades and parts of the upper walls of the main nave (mainly the northern wall) and the basement of the northern wall of the hall were preserved (Fig. 5). New sculptural (friezes and some of the capitals) and architectural (groined vaults, ashlar stonemasonry and horseshoe arches, for instance) elements demonstrate that artisans trained in (southern) Islamic technology were responsible for this outstanding construction and its decoration. Since this church was besides part of a monastery, it is supposed that further surrounding structures are to be found in this hitherto unknown and non-excavated site.

During the Middle Ages, some transformations took place in Mazote, affecting these to several elements, such as the northern wall, which was possible ruined and remade in the late medieval period. Later on, during the Modern Age, the southern wall was dismantled in order to attach further rooms and houses to it. Another building, probably a sacristy, was added to the south-eastern side of the chancel and a timber roof inserted in the aisle and the crossing space (Gómez-Moreno, 1919, p. 184). The church was then hidden behind these surrounding spaces, which also changed its internal use by introducing new accesses both in northern and southern sides. These new spaces show indirectly that those structures belonging to the original monastery could not be in use any longer.

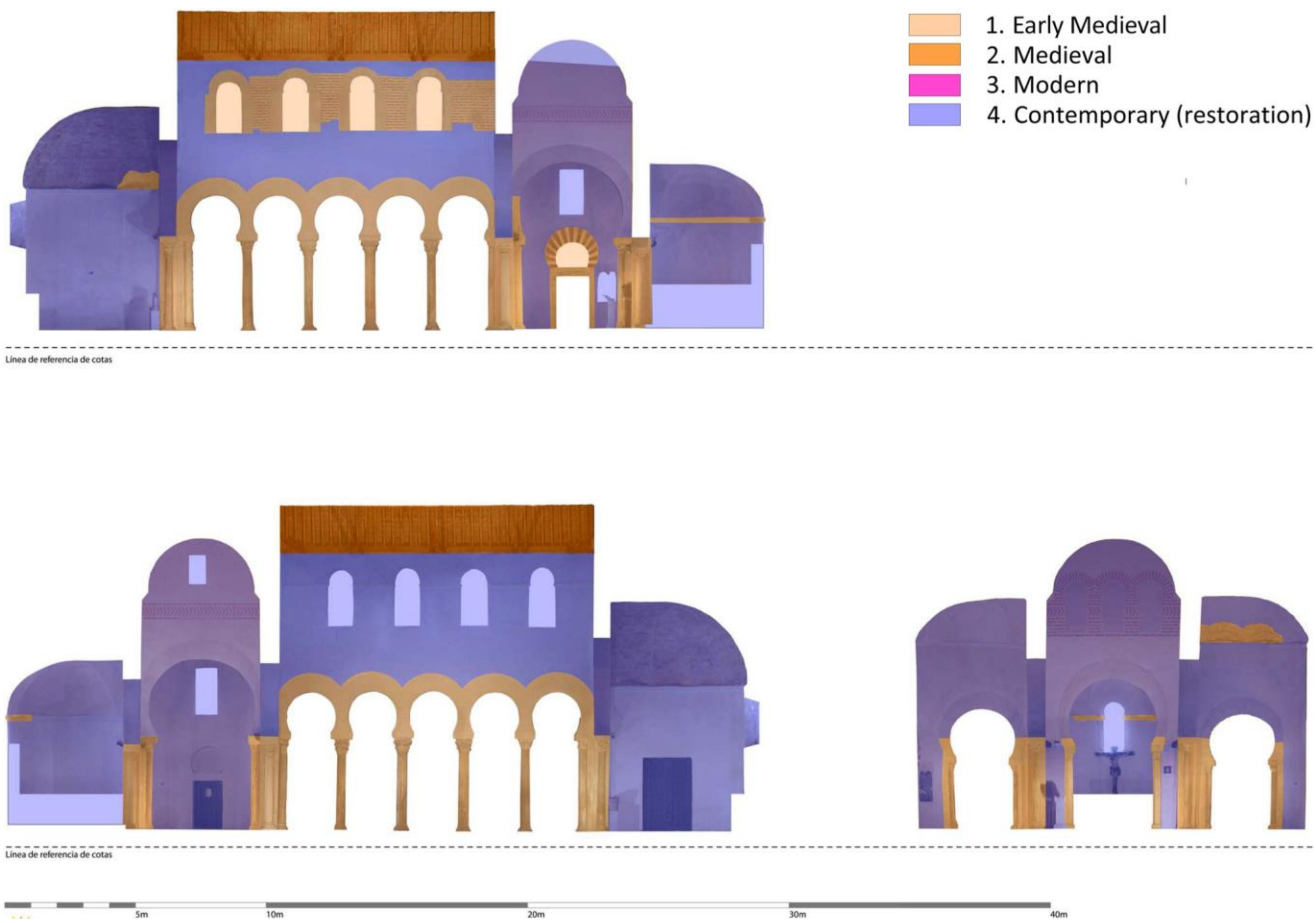

Fig. 5: Transformation sequence of main inner spaces

Furthermore, the outstanding western bell tower, built in a remarkably dressed ashlar stone masonry (Fig. 4), was added by a workshop of masons working in the area at the end of the 18th century, along with others rooms and elements currently lost, such as a northern baptistery and the brick vaults of the aisle and the crossing space (replacing here the previous roofs; Gómez-Moreno, 1919, p. 184). This bell tower was the first element of a project intended to demolish (from west to east) and replace the Early medieval church of Mazote by a modern one. This project was fortunately not undertaken.

After its scientific discovery in the early 20th century and its later protection as National Monument in 1916, it was deeply restored by the architect F. Íñiguez Almech in the thirties. In order to recover the Mozarabic church, Íñiguez dismantled almost all later additions, but the western bell tower, and rebuilt in brick the main structural elements, such as the vault covering the counterapse (Fig. 6), the main apse and the transept; and the upper part of the walls of the main nave and the crossing space. He recovered the basas of the arcade, hidden by a higher modern pavement, and built as well a northern sacristy and a southern baptistery to make possible the use of Mazote as the parish church for the village where it is sited.

The currently existing building corresponds so to the ideal model of this restorer regarding the so-called Mozarabic constructions and to the necessities of contemporary uses. For instance, the vault over the crossing was completely constructed, although no remains of such a structure had been preserved (Fig. 7). It is actually doubtful if this space was covered with a vault or a timber roof (Utrero, 2006, with previous bibliography on this discussion). Avoiding this problem, Íñiguez took the model of the groined vault covering the crossing of the church of Santiago de Peñalba (León, early 10th century, Fig. 8) as example to be reproduced in Mazote (Mata, 1992, p. 125; Rivera, 1997, p. 66). The heights of the wall and the dimension of the southern lateral space of the transept were also

Fig. 6: Contemporary brick vault covering the counterapse of Mazote. Remains of the early medieval vault may be observed in the lower part of the image

Fig. 7: Contemporary vault covering the crossing space in San Cebrián de Mazote

interpreted by the restorer without having analysed previously the building and being thus not sure about the original dimensions and forms of these rooms. The current shape of the building is therefore a full-scale model of the restorer's interpretation (Fig. 9). Contemporary restorations (S. Mata, 1992) hided besides the internal surfaces of the walls by applying a thick and homogeneous layer of stucco (Fig. 10).

Fig. 8: General view of the church of Santiago de Peñalba (León)

Fig. 9: General external view of the church of San Cebrián de Mazote

Fig. 10: Central nave of the church of San Cebrián de Mazote

4. Advanced 3D models for dissemination

4.1 Applications of 3D models

Once that the main results of the archaeological and geological analysis of the church of San Cebrián de Mazote have been shown, it is our aim now to discuss some ideas regarding the use of the 3D model obtained, as well as the aspects which have to be addressed in order to develop an advanced one.

3D models of historical buildings have become a powerful and quite popular tool thought to offer great advantages in regard to both research process and dissemination activities. In our opinion, the analysis of the building by means of the Archaeology of Architecture methodology does not need any 3D representation to be properly done, but just a complete and rigorous group of architectural drawings, such as horizontal and vertical sections as well as external façades. Contrary to the common opinion, we think that 2D architectural drawings are still the main research tool to analyse historical buildings (Caballero & Murillo, 2006; Martín Talaverano, 2014), since geometrical information is not easily accessible enough in 3D models and the spatial and geometrical analysis can be much more easily achieved by traditional architectural drawings.

However, there is no doubt that 3D models are certainly a quite powerful resource to generate such architectural drawings. Indeed, in some particular cases the 3D model itself can provide a significant support for the constructive analysis, especially when comparing the spatial configuration of unrelated elements, such as the inner and external surfaces of a same wall. They can be also helpful to check the volumetric compatibility of the hypotheses regarding the study of currently lost spaces. Besides that, the pathological analyses may remarkably take advantage of having a full 3D representation of the building, since the distortion of walls and piers may be checked everywhere.

It is within the frame of dissemination where such models actually play an essential role. The comprehension of a whole spatial structure by using planar projections (like plan layouts, vertical sections and external façades) is not an achievable challenge for many non-specialised people. That is why 3D models certainly provide a quite important help to physically view and understand buildings (Fig. 11). In this way, it could be said that the visualisation and dissemination of historical buildings is the most important application of 3D models. External views of buildings using such 3D models are quite effective, given that the user can easily perceive the whole formal configuration. However, inner perspectives are difficult to manage, since there are usually many undesired objects which obstruct the view and make it complicated to understand the spaces. For this reason, when a metric analysis is not required, such 3D models can be substituted by 360º or 180º images, which are undoubtedly much easier to get and manage.

This fact leads us to try to define the specific requirements and needs that an advanced 3D representation of historical architecture should deal with. Beyond the specific characteristics of the survey and 3D modelling, we could summarise the detailed aspects regarding the visualisation under four main topics:

1. Evolving sequence of the building.
2. Contextualisation of the building.
3. Virtual reconstructions of lost parts of the building.
4. Accessibility to the research process.

Fig. 11: Visualization of external 3D model of San Cebrián de Mazote and inner 180º photography

Fig. 12: Visualization of the evolution of the building through its 3D model

The following sections will describe each one of such issues in relationship with their application in the 3D model of the church of San Cebrián de Mazote. It must be said that our aim has not been (by the moment) to develope any methodology for the proper management of such concepts. Thus, the following paragraphs are not proper results of a specific research, but the proposal of a more efficient and rigorous approach to the historical architecture by using 3D models of buildings based on their complex essence as described before.

4.2 Visualisation of the transformation sequence

The first topic that an advanced visualisation of historical buildings should deal with is the communication of their transformation sequence. It is important to present a building not only in a precise moment of its life story, but also to somehow visualise its evolution throughout the time. Some progresses have already been done in this direction, and there are currently available a few examples of the so called 4D models of historical architecture (Kersten, Hinrichsen, Lindstaedt, Weber, Schreyer & Tschirschwitz, 2014), which include the time as a complementary dimension of the three spatial ones.

In our opinion, one of the most interesting approaches developed with the aim of implementing the temporal dimension to manage the transformation sequence of buildings (Stefani, 2010) is based on Renole's historic graphs. This work sets besides important concepts such as the type and duration of transformations. In our case, a 4D model for the church of San Cebrián de Mazote might be obtained thanks to the archaeological analysis, showing the aforementioned historical phases: Early Medieval, Late Medieval, Modern and Contemporary restorations (Fig. 12).

4.3 Visualisation of the building's context (metadata)

As we have seen, the complex essence of historical architecture is composed by its evolving nature, as well as its contextualisation within its technological, social, geographical and historical environment. For that reason, an advanced 3D model should include and allow the user to check and manage several metadata related to such context. This can be achieved by linking the 3D model with a set of multimodal digital data covering a widespread range of information: images, audio-visuals, sound effects, texts, etc.

Since the research of San Cebrián de Mazote was developed by means of an interdisciplinary methodological approach, following metadata coming from different fields, which help to reconstruct the context of the building, might be included:

Archaeological metadata might incorporate the information of every single stratigraphic unit (detailed typological description, relationship to others units and interpretation, for instance) gathered in the archaeological recording sheets. In Mazote, more than 150 stratigraphic units were identified, which break up the construction in minor information capsules.

Geological metadata might include the visual and petrographic characterization of the stony materials in the building, in the original quarries and stored in museums and collections. In Mazote, this information has been got both in the building and sculptural elements preserved in the building, according to its position in the stratigraphic sequence, making possible to identify the nearby quarries where the limestone was exploited.

Historical metadata might be composed by data provided by epigraphic monuments placed in the building (always considering its place in the stratigraphic sequence) and by palaeographic and graphic records stored in historical archives. In Mazote, no epigraphic sources have been preserved, but palaeographic records make reference to the likely date of foundation (ca. 916) and graphic records show us the state of the building before the early 20th century restorations, when it was still surrounded by historical constructions, of which the traces have been recorded by the archaeological analysis.

Structural metadata might incorporate the historical cracks and movements of the building

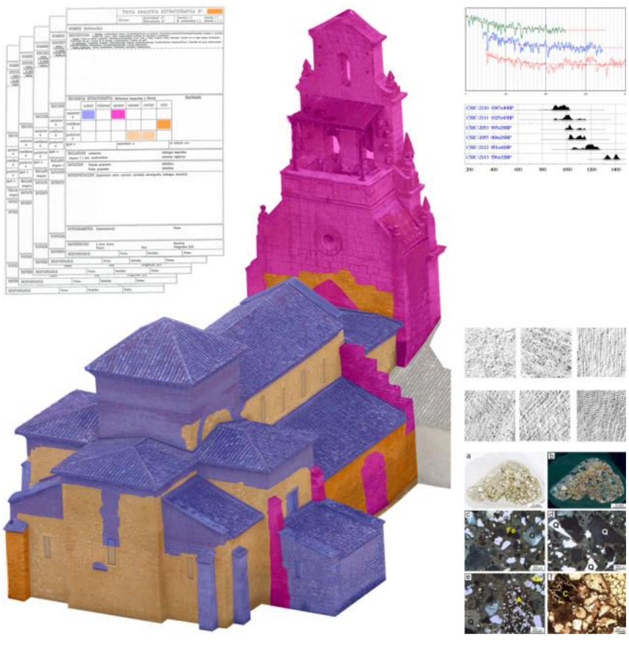

Fig. 13: 3D model of the church of San Cebrián de Mazote with implemented metadata

and the current state of preservation in order to propose a sustainable maintenance plan or future restorations works, for instance. In order to properly record such structural movements and traces, it is important that the 3D model preserves the actual distorted geometry of the constructive elements. For this purpose, no simplified 3D model to a "straight" or "lined up" geometry should be accepted. In Mazote, the almost complete destruction of the northern wall of the hall in medieval times and the subsequent movement of the building in later periods might be here considered.

An advanced 3D model should thus address the implementation of such data together with the spatial and geometrical information of the building (Fig. 13). It can be nowadays achieved thanks to the BIM technology, so that the 3D model would then become a digital database that organizes and preserves a complete set of digital interdisciplinary information. Some efforts have already been done in this direction, generating efficient tools for the management of the information regarding to historical buildings (www.petrobim.com).

4.4 Visualisation of virtual reconstructions of buildings' lost parts

One of the most powerful applications of 3D models is the representation of virtual elements or parts of the building that no longer exist. It is indeed a quite attractive resource for users in order to understand how the building was originally and how it has changed throughout its life story, showing thus this concept of real structure already mentioned. But at the same time, such virtual reconstructions may have significant negative effects, since it is possible to communicate a non-rigorous message when they are not transparent and clear enough.

Some authors have already addressed the representation and semantic management of hypothetic restitutions, using several graphic resources, such as transparences and colour codes (De Luca, 2011 and 2013). Related to this, it is to be highlighted the interesting work which collects the website designed by Tayfun Öner (2011), Byzantium 1200, for rendering the "Portus Theodosiacus" (http://www.byzantium1200.com/port_t.html), where it has been defined a "scale depicting historical and archaeological evidence". In such scale, the authors intend to classify the virtual reconstructions of lost elements depending on the higher or lower degree of existing evidences that support the interpretation of the archaeological site/building.

This approach sets an appropriate point of view for the future development of new 3D virtual models of non-existing objects. However, in order to improve it, a theoretical nuance could be introduced. Instead of classifying the categories with a quantitative index, that is, depending on how many evidences the interpretation is based on, we intend to propose an alternative qualitative approach. This means that each category may be associated with a different source of data for establishing evidences:

1. Existing elements; there is no interpretation.
2. Material remains that support the interpretation.
3. Interpretation based on the constructive or compositional features of the building.
4. Interpretation based on existing elements that are used as parallel ones.
5. Interpretation based on written and/or oral sources.
6. Interpretation based on theoretical models.

It is important to highlight that this is not a progressive step-by-step classification in which each category grows or diminish its specific degree of evidence in comparison to its precedent or follower one. Although categories 1 and 2 are undoubtedly much more reliable than the others, it should not be a priori assumed that there is any kind of reliability progression between categories 3 to 6. In any case, each category could have its own quantitative scale of evidence.

Given that one of the main objectives of the research project of Mazote has been to identify its currently existing early medieval elements, it has been also possible to use the 3D model in order to show an interpretation of how the building could have been in its original period. For that purpose,

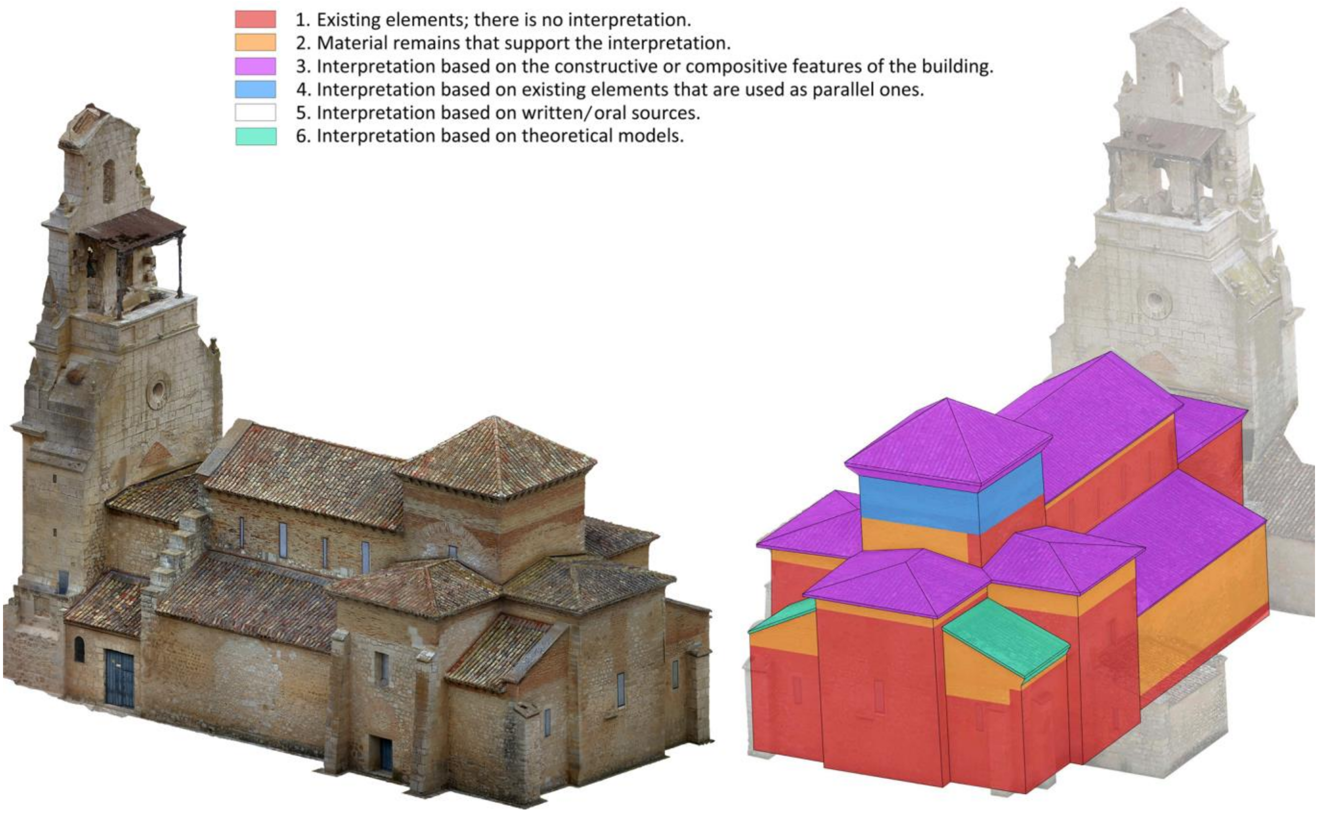

Fig. 14: Virtual reconstruction of the initial early medieval church using the proposed scale of evidences

the above mentioned conceptual classification of the interpretations undertaken during the development of the research has been applied (Fig. 14). This approach will certainly help to understand which scientific arguments support the virtual reconstruction of lost elements.

4.5 Dissemination of the research process (paradata)

Implementing issues about how virtual reconstruction of lost parts has been made in a 3D model actually means the dissemination of the interpretation process. This leads us to propose that the information regarding the research process should be implemented in advanced 3D models, in the same way that they should be able to visualize the transformation sequence and the contextualization data of the buildings. That is precisely how paradata could be very useful for.

Given that our main scope is to understand the evolution of the society by means of the evolution of the historical architecture, we should focus on the material and immaterial traces which are produced by transformations. These are to be summarised in two categories: elements resulted from constructive actions, which correspond to positive stratigraphic units; and elements caused by destructive actions, which are negative stratigraphic units (also called interfaces). Both of them might have a human or natural origin, intentional or not. Such material (positive) and immaterial (negative) traces are very important data for the study, given that they may support or reject initial hypotheses, and their proper visualization can help to understand the research process. That is why they should be implemented in advanced 3D models by means of attached multimodal data, tags or even by using BIM technology (Fig. 15).

According to Baker (2012, 179), paradata might capture "the selection, evaluation and exploration of ideas, as well as entropy and cultural assumptions, research and technical decisions, inference and implied possibilities and

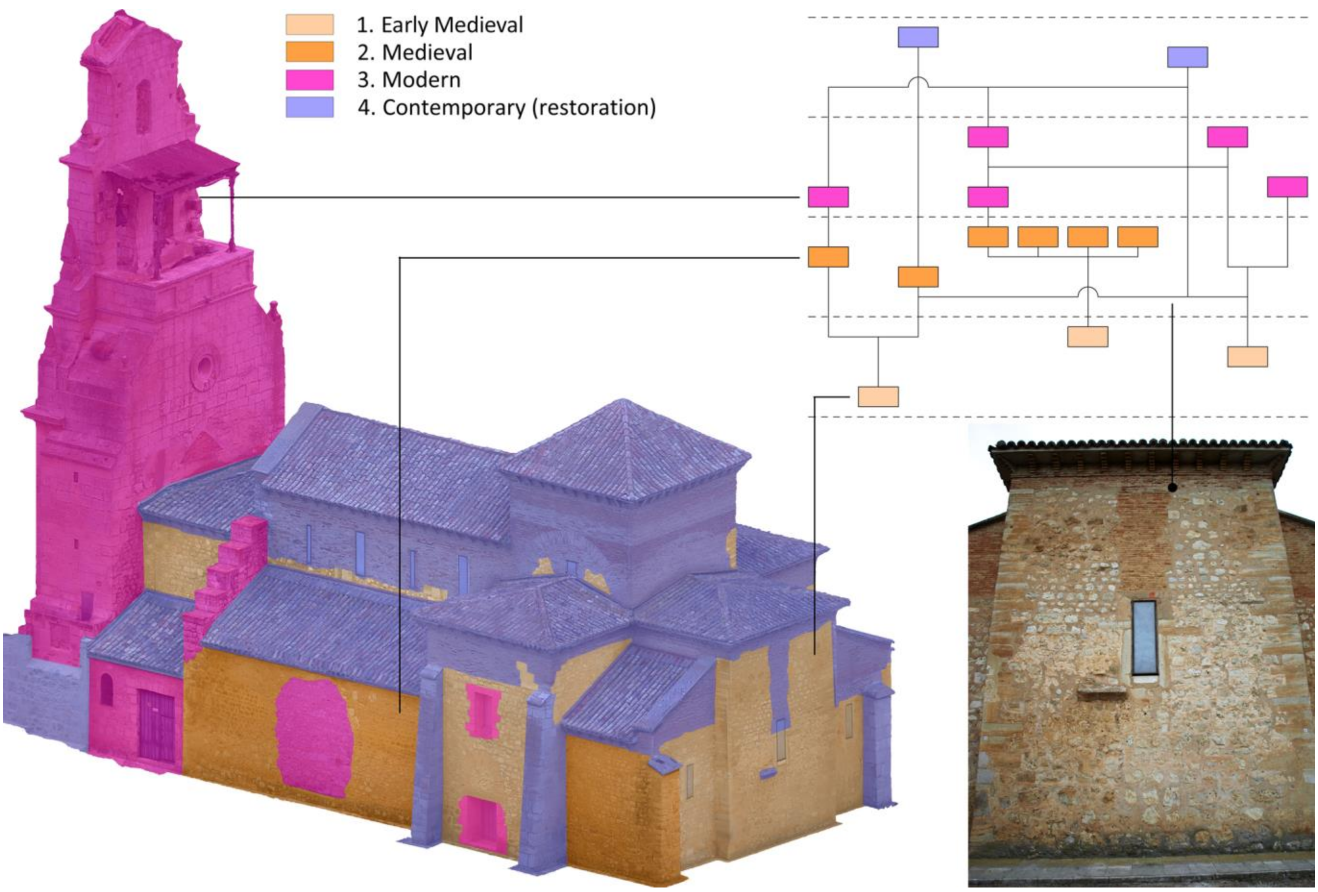

Fig. 15: 3D model of the church of San Cebrián de Mazote with implemented paradata

probabilities". To show this process is a challenge for the improvement of 3D models.

We will show an example coming back to Mazote. When analysing the building archaeologically, the discussion among the different specialists involved on the limits of both positive and negative stratigraphic units is a source of information regarding the technical process and the arguments employed to arrive to a final output. Main points are recorded within the archaeological sheets, and are those which we have called metadata, but that discussion undertaken in the field and later on when summarising those units remains hidden. This is only gathered as a final archaeological sequence or diagram (Fig. 15). This one could be adressed by all that information, and should also be stored in the 3D model as a spatial full database.

5. Conclusions

The work developed during the survey, modelling and archaeological analysis of the early medieval church of San Cebrián de Mazote has given us the opportunity to reflect on the current applications of 3D models as well as on the future challenges that the research should address in order to obtain advanced ones. The 3D model converts itself besides into a useful instrument to store the historical and archaeological results of the study, which can be easily updated in the future by adding information of further works.

As it has been aforementioned, one of their main application fields is undoubtedly the generation of graphic recording, although under no circumstances should they substitute the onsite thoughtful work of direct analysis of the material objects. Besides that, 3D models are already playing an important role in regard to the dissemination of cultural heritage objects. They are certainly a quite important tool to help visualising the objects themselves, since such digital replicas are widely accessible for a greater number of citizens. They have a clear potential regarding the creation of digital open databases, and as a matter of fact they may become powerful communication resources to be implemented in virtual museums.

But the search for the development of advanced models should not stop here. Recent works have achieved to incorporate the temporal dimension in order to generate the so-called 4D models, which somehow are able to show the transformation sequence of historical buildings, that is, their evolving nature. Besides that, some projects have addressed the implementation of databases into 3D models by using BIM technology (metadata), while some others have dealed with the specific requirements of the representation of hypothetical elements resulting from interpretative analysis. What is more, works such NUBES project have developed a semantic-based platform that integrates some of the aforementioned concepts (De Luca, 2011).

At this point, we might ask ourselves wether any other approach should be added in order to enrich the development of historical buildings' 3D models. This question has driven us into a really new perspective that has not been hitherto attended by any research.

It consists basically on the implementation of the main data and the key points of the analysis and interpretation processes undertaken by researchers of historical buildings. What we propose is not only to include the key aspects regarding the investigation and discussion about the building's transformation sequence in its 3D model, but to actually create it in such a way that the model is based on the stratigraphical relationships between the building's constructive elements. These paradata would then play a fundamental role, so that the development of advanced 3D models should address their implementationin an interactive environment. The user will be able therefore not only to fully understand what is shown, but also to take part in an active and participative learning. Making possible the comprehension of the research process will help to develop a critical understanding of the complex essence of historical architecture, allowing citizens to freely understand and enjoy our cultural heritage.

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