12 Years of Archaeological Data Digital Registry at the Santa María Cathedral of Vitoria-Gasteiz (1997-2009)

Koroso, I.[1], Muñoz, O.[2]
[1] GIS Manager
[2] C.G. Technician
{ikoroso,oscar}@catedralvitoria.com

Over the last 12 years, the Cathedral of Santa María and its surroundings have been the object of intense archaeological research, during which Archaeology of Architecture has been applied, both to the excavations and to the monument. All the data obtained and analyzed is digitally recorded and can be managed with a Geographical Information System of the monument. This article explains the different methods that have been used to register data, analyzes their advantages and disadvantages, and outlines the key structures for the future of the Monument Information System.

Keywords: GIS, Archaeology, Database, Heritage

1. Introduction

The Cathedral of Santa María Foundation is responsible for the restoration of the Cathedral of Santa María in Vitoria-Gasteiz. Before the restoration works even began, a Master Plan was developed in which more than 25 work teams participated, receiving the 2002 Europa Nostra Award for architectural studies. On one hand, the architectural side of the project focuses on the study of the construction, the function and the formal aspects of the Cathedral, and on the other hand the historical side of the project analyses the monument as a vessel which holds hundreds of years of history, which must be interpreted.

The concept of archaeology of architecture has been applied systematically by the *Basque Country University Built Heritage Research Group (GPAC,UPV-EHU)* during the last 12 years while interpreting all the material remains of the monument, from those corresponding to the present-day stone that the cathedral is made of, to all the other structures, objects, and materials that have appeared during each of the excavation programs that have been carried out.

2. Geometric documentation

The archaeological research has focused on the Cathedral system, including both the monument and the soil layers beneath it. The hugely complex physical distribution of all the elements requires specific techniques in order to represent them geometrically.

2.1. 3D model of the monument

In order to geometrically document the monument's elevations, a three-dimensional model of all the elements that make up the cathedral walls has been created. Close range photogrammetry has been used, because it allows geometrically precise data to be registered and a visual reconstruction in three dimensions to be obtained, thanks to the stereoscopic properties of each pair of photographs.

In order to create the geometric model, the Cathedral was divided into constructive elements, based on classical studies of Gothic construction techniques. In this way we can understand the building from the point of view of its material construction instead of its visual architecture or its theoretical structure.

Managing the whole model was a complicated task, bearing in mind the type of computers that were used in 1996-98. Each constructive element was assigned a file, which was then represented by a line on the key map that represented the Cathedral. The model featured 859 files covering the outside of the Cathedral and 357 for the inside (AZKARATE *et al.*, 2001:86-195).

Subsequently, in 2003, the model was reorganized based on the location of the elements within the Cathedral, simplifying its management. At the moment the model includes 46 indoor files and 21 outdoor ones.

Over 1,600 such photogrammetric pairs have been used to create a 3D model of the walls, featuring more than 500.000 CAD entities.

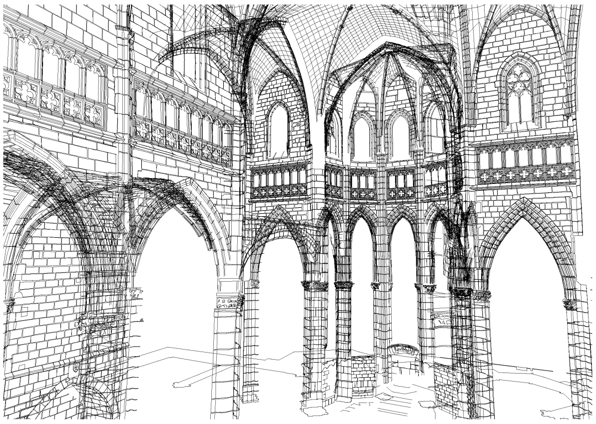

Figure 1: *3D photogrammetric model of the cathedral walls*

2.2. Geometric documentation of the excavations

When carrying out excavations in complex places such as the Cathedral of Santa María and its surroundings (fig. 2), it becomes especially important to be very precise regarding the physical distribution of the different elements that will be excavated. When we deal with what is underneath, very rich in constructions and burials, a high degree of precision in the geometric documentation has allowed us to clearly establish connections between the position of the burials, walls and other elements that have no visual connection with each other, thus shedding more light on the historical and constructive evolution of the building.

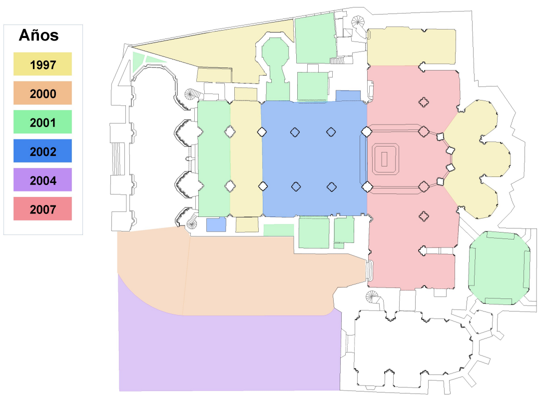

Figure 2: *Layout of the excavation according to the starting years of each campaign.*

Applying photogrammetry to archaeological excavations fulfills a double objective. On one hand it provides good quality geometrical data, and on the other it offers the possibility of visually examining the excavation, thanks to the stereoscopic model that is generated with each photographic pair. However, systematic application of this technique involves a series of costs, in terms of both budget and time. Bearing in mind these issues, during the excavations carried out over the last 12 years at the Cathedral of Santa María, the photogrammetric registry has been complemented with classic topography. The relationship between both techniques has evolved throughout the different excavation campaigns, according to the development of the registry methods and the management of the information that has been obtained, as well the assessments of the work methods carried out after concluding the excavations in each area.

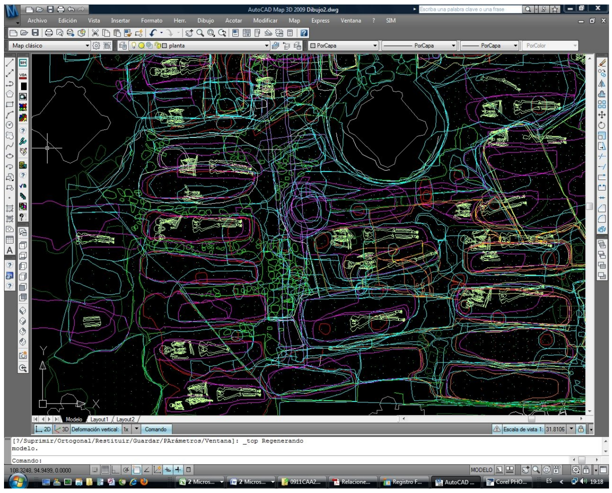

Figure 3: *Geometric representation of the excavations.*

Sectors 11 and 12. Beginning of the excavations: 1997-1998 years

During the first campaign in 1997-98, applying photogrammetry to excavations was an innovative technique that had been applied to the excavations at Santa María de Melque (Toledo, Spain), directed by Luis Caballero Zoreda (CABALLERO *et al.*, 1996:14-25). Photogrammetry was applied to the documentation regarding the previously estimated period plan, while classic topography and metric drawings drawn up by archaeologists were applied to the rest of the geological strata.

At the time, digital photography was not in use, and the topographical equipment that was available could barely register the readings that were made. The task of obtaining topographical data required a huge dedication, so it was decided to use photogrammetry to document the stratigraphic units referred to the period maps (as was estimated during the excavation and therefore provisional). The rest of the elements were georeferenced using archaeological drawings, while classic topography was applied to determine the levels.

The linear representation is more complex in an archaeological site that in the wall of a monument. Interpreting the three-dimensional model of a building is relatively easy, since the edges of ashlars, masonry or other elements of the building are represented. However, when representing an archaeological site, the irregular nature of its elements (tombs, walls, levels) make itmore complicated for an observer to visualize the site. In order to overcome this problem, it was decided to apply a methodology that would allow the excavation to be observed using a three-dimensional linear model. Based on the concept of DTMs (Digital Terrain Models), a working process was developed so that a representation of the surface could be created using fixed-size squared cells. (Fig. 4).

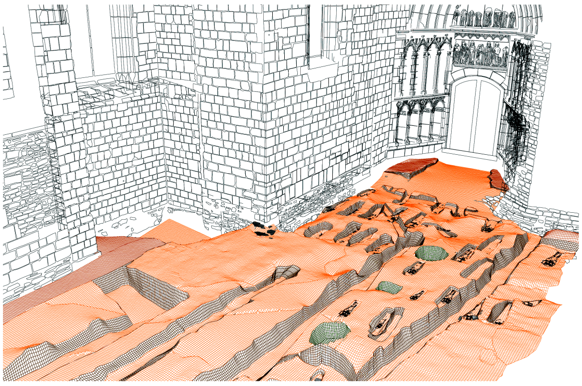

Figure 4: *Mixed visualization of both the elevation-plans and the excavation mesh using the semi-automatic meshing tool.*

Santa María Square, Phase 1. 2000-2001years

Santa María Square is located in front of the South-facing wall of the Cathedral. In order to give the whole excavation the same geometric precision, it was decided to use photogrammetry to register all stratigraphic units. Thus, each unit was registered twice: first archaeological drawings were made during the excavation process and then a new cartography with pairs of images was generated for its inclusion in the SIM.

Due to the considerable size of the excavation, it was not possible to install an additional fixed element that could reach an acceptable height from which to shoot the photographs, so a custom-made structure was designed to allow images to be taken of any of the excavation areas (MESANZA *et al*., 2003). This system is placed on the surface that has to be photographed , and it allows the camera to be moved over the axle without having to move its stand. This way the necessary requirements and conditions for taking photographs are fulfilled.

Nave and aisles. 2002-2003 years

Documenting all stratigraphic units with photogrammetry during the excavations between 2000 and 2001 meant a huge increase in the resources dedicated to geometric documentation, forcing the managers of the excavation to analyze carefully the balance between the amount of work dedicated to this task and the correct representation of the excavations.

For this phase, it was decided to use photogrammetry for the stratigraphic units that corresponded to period maps, and to use archaeological drawings for the rest, making the excavation process more agile.

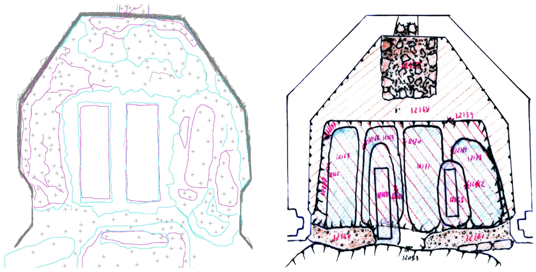

Figure 5: *Archaeological registry by photogrammetry and archaeological drawing.*

Santa María Square, Phase2. 2004-2006 years

During an archaeological excavation there is a huge amount of registered data, from the coordinates of a unit or photographs of the findings to the analyses of the composition of the mortar in a buried structure. It is essential to make an integral plan of all the tasks involved in registering data and to keep a good balance between them all. Obviously such analysis will influence the methodology that is chosen.

The systematic application of the photogrammetry technique to each stratigraphic unit slows down the process of excavation and restitution, making it also more expensive. The constant process of evaluation and improvement of the data collection methodology reached its culminating moment with the proposal made for the excavations of sector 26.

At this time it was decided to substitute archaeological drawings with tacheometry maps made on site, while also creating pairs of each of the geological strata. The photographic pairs were taken from a track located along the cover structure. The time employed to make the archaeological drawing is also used to mark representative points using classic topography. The download of this data is synchronized by a custom-made format by assigning a specific colour to each point, placing them on their corresponding layer and linking them to a specific register within the database. This way an updated registry of the excavation is obtained without the need to increase human resources, while reducing lab work. To complement this, a pair of photographs is taken with their control points in order to allow photogrammetric restitution, a process which will only be carried out on outstanding elements whose importance requires detailed representation.

Transept. 2007-2009 years

When evaluating the methodology used in sector 26, the results were very positive, and so it was used also to document sector 29. As a novelty, it is worth noting that a semi-metric digital camera was used to shoot the photographic pairs, along with its accompanying digital stereoplotter, providing all the benefits of digital systems (flexibility, immediacy and savings in developing costs). Another characteristic of this phase was the application of aerial triangulation to obtain photogrammetric pairs, a technique developed for the process of photogrammetric data gathering: the concept of stereoscopic pair is substituted by photogrametric strip, in such a way that a series of photographs are taken along the same moving axis, allowing stereoscopic pairs to be made between two subsequent photos. The great advantage of such a method is that we do not need to find supporting points for each pair. In this technique a pair is progressively obtained and the supporting points will be found on the next one, which saves a lot of field work time.

As in the previous phase, archaeological drawings were substituted by tacheometry obtained through classic topography, and all units were documented using photogrammetry, allowing future access of the information, both visually and metrically.

3. Databases

As we have pointed out before, the database is created following a structure based on unique values assigned to each registry, which are called “key fields”. This allows us to expand the information according to the level of detail we require. When defining the connections between the different tables, we indicate the type of connection established by choosing between various types: one to one, one to various or various to various. The summary of these connections can be found on Figure 5.

As well as the alphanumeric information that is contained in the different tables of the database, the system also manages a large number of images: photographs, sketches and vector drawings. This is carried out using forms that are personalized for each level of data. The output of data is completed through a series of reports that were previously designed to physically store the required data.

The database includes a series of macros and tools in Visual Basic for Applications language that carry out complete calculations. These tools are vitally important in order to carry out tasks of data reorganization. Although the data model needs to be pre-established, it is not unchangeable and so the initial project is enriched by details that will result in further data or in the revision of existing connections.

The contents included in this database are over 11,000 entries regarding the stratigraphic units, more than 2,000 records about burials, dozens of tables regarding partial aspects of the main table, the management of over 3,000 photogrammetric pairs which have been made and more than 20,000 image files.

The database used for the archaeological registry is called HISTORIA.MDB and is made up of a series of tables related to each other by some common fields. Here below is the description of the content of this database.

Main Tables: Units table which contains all the general information related to the Stratigraphic Units, and the tables *DataDeposits, DataSurfaces, DataSolutions and DataElements*, which describe the characteristics that are specific to the corresponding type of unit.

- Index tables: they define which values are shown in the drop-down menu related to each field. Examples of such tables are *tblAreas, tblBonds, tblSketches, tblSlides, tblJoints, tblMaterials, tblMortars ...*

- Reference tables: the paradigm of relational databases establishes that one or more fields in each table need to identify exclusively the corresponding entry. These fields are called IDs and they are used to cross-reference entries amongst different tables. Such cross-references are indicated in this type of table, which include: *tblRefBonds, tblRefSketches, tblRefSlides,...*

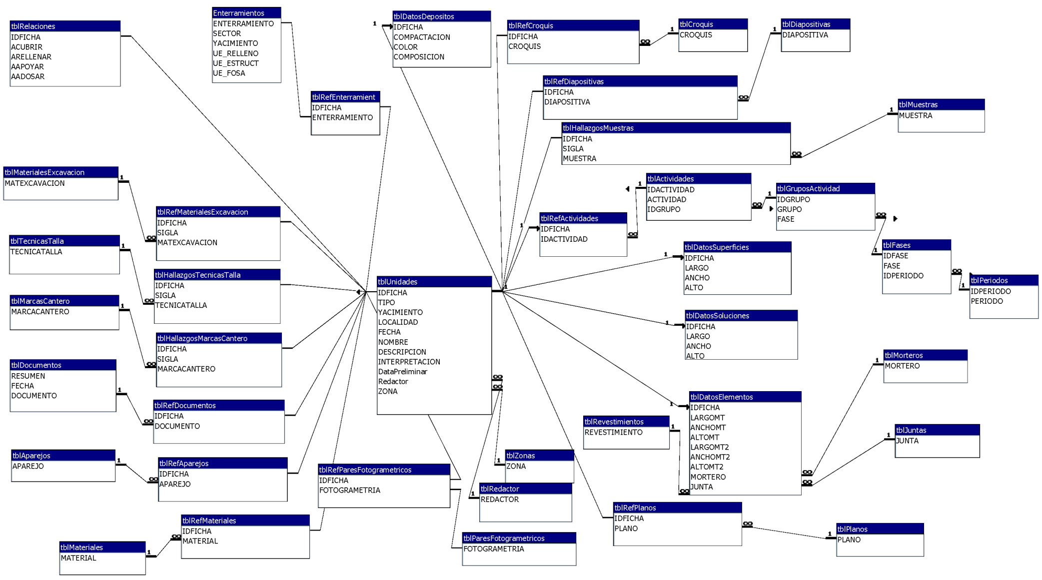

Figure 6: *Relational scheme of the tables of database.*

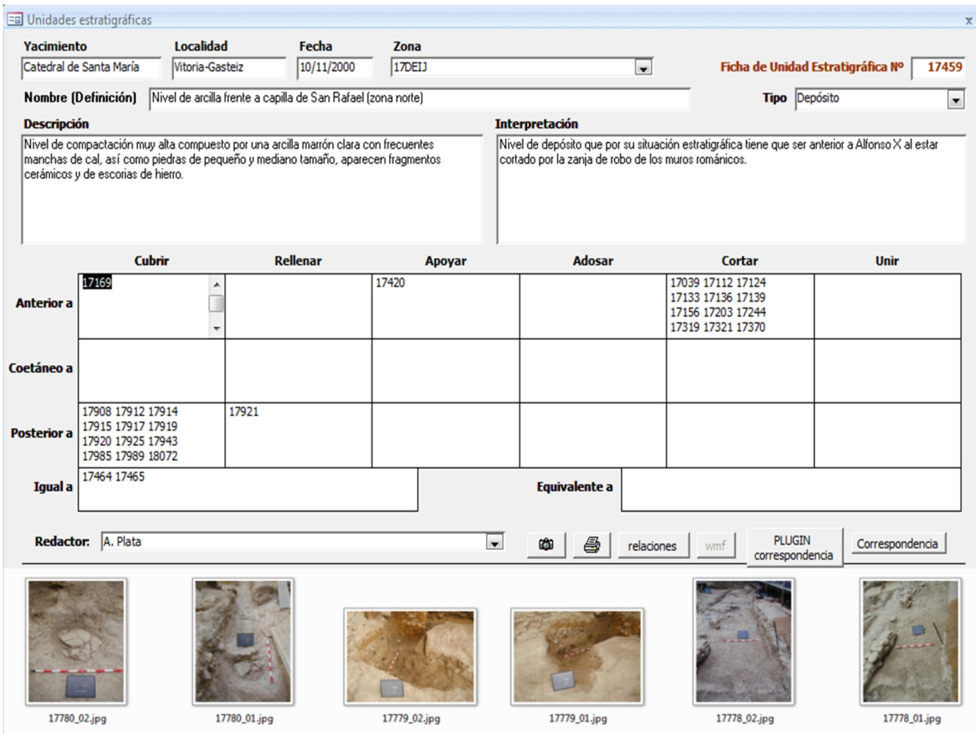

Figure 7: *Form of the main tables of database.*

- Special tables: due to the role they fulfill and the structure the possess, there are four specific functions of the database that are interesting to highlight and explain:

TblSequence: In an excavation, a series of minimum study units appear, called Stratigraphic Units. These units are related to each other following criteria of time (earlier, later, coeval), and of construction (cover, fill, support, bond, cut or join). These relationships are bi-directional, since if A comes before B, then B must come after A. The analysis of this data is essential in order to comprehend any study that is based on stratigraphy. In our case, there is a specific table for that task whose key field is the Stratigraphic Unit, while the rest of the fields are made up of different combinations of time and construction criteria. When introducing the data, it is included in a form together with the rest of characteristics of the unit, allowing all the characteristics of the main table to be seen. Corresponding relationships between two different stratigraphic units (UEs) are controled by means of a specific programming module.

Grouping levels: Throughout the different phases of excavation of the Cathedral, over 11,000 UEs have appeared. In order to design the diagram of activities, it is necessary to establish levels of grouping in such a way that various UEs group under Activities, a number of activities become Activity Groups, various Activity Groups become a Phase and various phases make up a Period. This results in 5 tables with relationships of one to many, creating a flexible data model that allows the groupings to be revised while maintaining the referential integrity of the data.

Burials: During the excavation, unique elements appear that are appropriately documented. Burials, for example, are assigned a Deposit UE for the filling and a Surface UE that identifies the interface, but they are relevant enough elements to deserve specific documentation. For this reason, we have defined a table to include the characteristics of the burials and a form which includes photos of the burial and other aspects such as its position in the terrain.

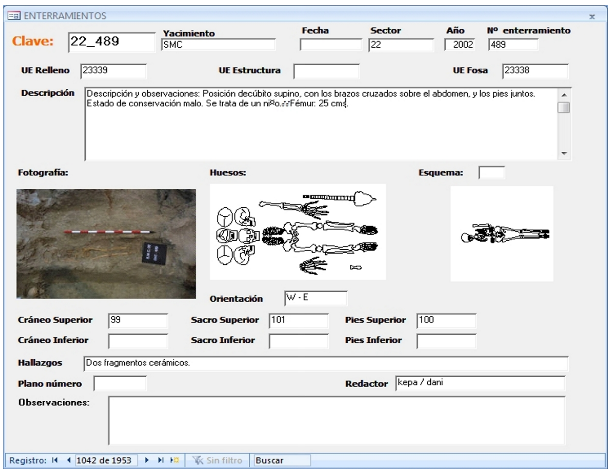

Figure 8: *Database used for documenting burials.*

Photogrammetry: The geometric registry obtained using photogrammetry has evolved throughout the different phases, generating thousands of images and supporting points. One of the main functions of this registry is to serve as a basis for later visual and geometric re-interpretations, so the efficient management of this data is essential. The information is organised in such a way that we can know in which images and with which supporting poins we will be able to recover the UEs which interest us. Information related to how the images were shot can also be consulted, such as the base between shots or the average distance to the object, in order to assess the geometric precision of the stereoscopic pair.

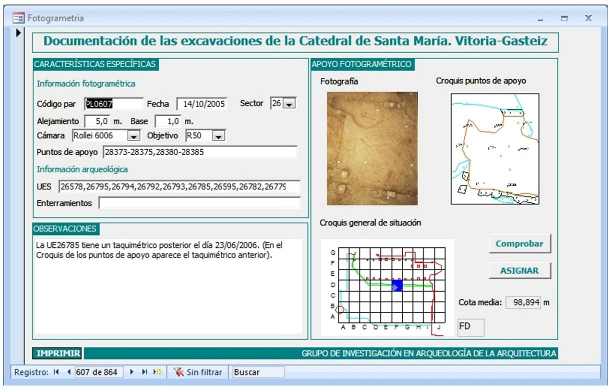

Figure 9: *Database used for photogrammetric registry.*

4. Monument Information System (SIM)

The management of all this data has been carried out by means of a geographical information system that has been applied to the monument and which has been called the Monument Information System (SIM).

The first module of management of the geometric and themed information was developed specifically by the programmers of the Cathedral of Santa María It must be noted that in 1997 there were no commercial solutions that allowed to work with three-dimensional vector data and databases. Later on, and having assessed all the different possibilities on the market, a switch was made to commercial software, which implied reorganizing the model.

The structure and management of the model is aimed at allowing any user who is accustomed to working with three-dimensional vector models to carry out the most frequent tasks, such as selecting parts of the drawing, consulting the values associated to it and generating themed maps. In order to make its management more accessible, the Cathedral of Santa María Foundation has programmed a number of modules to personalize the work environment.

The uses and possibilites of such data management are endless, and the user methodology of the application follows a basic structure. First of all, the user chooses which geographical data they wish to look up, for which there are a number of tools available that belong to the software itself, and others that have been added through programming. Selection criteria can be spatial (selecting a window or an area), according to attributes of the drawing (line colours, layers in the drawing it belongs to), or according to characteristics defined in the database (which are based on SQL language). Once the geographical information has been defined, data can be extracted by choosing the selected entity or a number of themed criteria can be defined and a series of graphic characteristics assigned, creating a thematic map.

Representing the excavations graphically has an added complication, which is that all the different levels that have appeared on site are visible, which makes understanding the drawing difficult. The possibility of showing the different soil layers according to their age allows the drawing to be organized in such a way that the different period plans are visible. These maps are not permanent and will evolve automatically as the archaeological research continues.

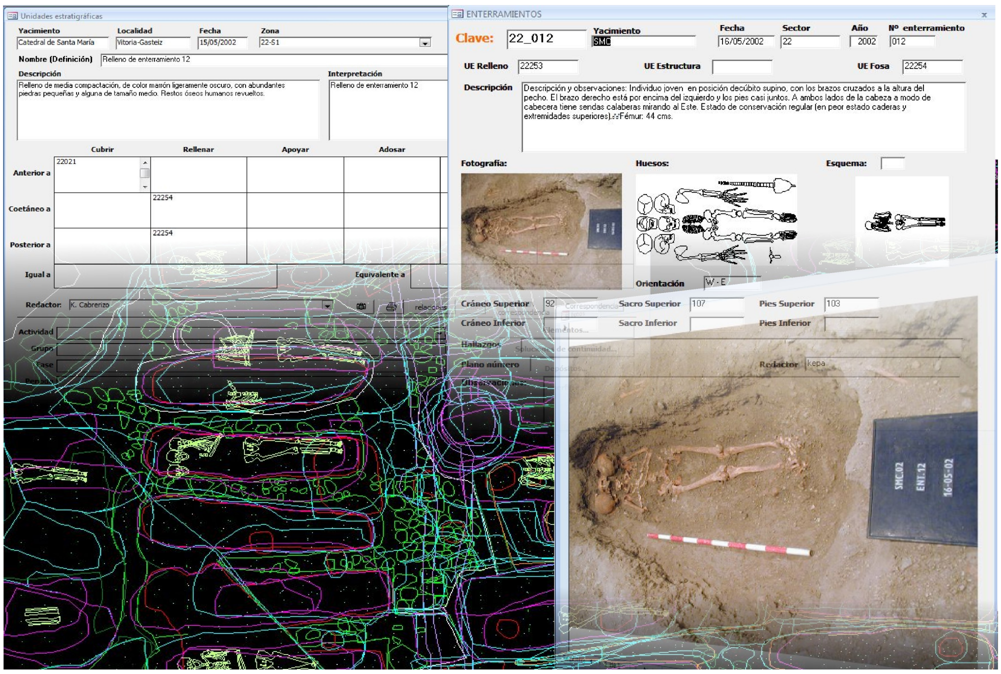

Figure 10: *Relation between images, data and geometric information in the SIM.*

5. Future

The aim of applying the SIM to the Cathedral has been to maintain a system that allows all the data that has been generated during the restoration to be documented and managed. At present it is used by the teams who participate in the restoration, but obviously such a powerful tool must also fulfill its potential to benefit the whole of society. Therefore the next step is being considered, which is to make all of this information available through internet

This phase requires a thorough prior analysis, carefully establishing the different user profiles that would be best to generate, indexing the information with the appropriate metadata, designing a user-friendly interface to allow agile navigation, and structuring the data so that all the information that is generated is automatically updated into the system.

Therefore the future involves putting all the knowledge gained through the restoration of the Cathedral out into the public domain, and with this aim, the tools used will be multi-platform and wherever possible it will be based on open-source software.

Conclusions

Excavating on location is basically a destructive activity in which the archaeologist is in charge of interpreting the results. For this reason the process of geometric and alphanumeric registration is of key importance for data use in corresponding studies, and it becomes essential if we consider it an activity that destroys material information.

Using photogrammetry provides the excavation process with geometric documentation that is precise and which allows visual reconstruction in three dimensions thanks to stereoscopic viewing.

The techniques for registry and management of geometric data are immersed in a process of continuous evolution and innovation, and so constant evaluation of the applied methodology is necessary. It is especially important to avoid falling into a routine or into a self-complacency that may paralize the highly-precise analysis of the appropriate tools that will, in turn, allow the goals that have been set to be fulfilled. In our case, the evolution of topographic equipment allows systematic use of classical topography to support and, in some cases, substitute photogrammetry as an alternative to geometrically defining some of the excavated elements.

The archaeological registry of the Cathedral of Santa María is made up therefore of geometrically precise, structured digital information that is accessible to users, allowing us to efficiently analyze the data we have today, and offering other investigators the opportunity to revise and expand the work in the future.

Acknowledgements

GPAC: Basque Country University Built Heritage Research Group (UPV-EHU). Workgroup in charge of the excavation. http://www.ehu.es/arqueologiadelaarquitectura/index.php

Laboratory of architectural documentation of the UPV-EHU. http://www.ehu.es/docarq/LDA/index.htm

LyC arquitectos: Execution of the three-dimensional model of the walls of the monument and beginning of the SIM

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