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Living the past: 3D models, virtual reality and game engines as tools for supporting archaeology and the reconstruction of cultural heritage – the case-study of the Roman *villa* of Casal de Freiria

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ABSTRACT

"Learn about the past to better understand the present and predict the future".

Although used abundantly to justify our interest in ancient societies, this statement lacks practical meaning due to the high degree of uncertainty which cloaks archaeological studies and theories, and the fact that there is no real way to prove or validate them. That is why it is so important to approach this study from a multidisciplinary point of view, providing several inputs which complement each other and so maximize the amount of factual information drawn from the analysis. Even then, the study will never be truly complete because there will always be a missing document, a small trace of an object (Verhagen, 2008), that still needs to be analysed.

This paper aims to be a useful contribution to historical research, specifically to the study of architectural history. Its purpose is to create a series of methods and tools for testing and analysing theories and hypotheses for historical scenarios (Vasáros, 2008) through the use of 3D modelling tools and Virtual Reality (VR) engines.

The project was developed in two stages:

The first was the creation of several three-dimensional (3D) models, each representing a different theory or hypothesis. The models were based on accurate Computer Assisted Design (CAD) (Autodesk® AutoCAD) models for the reconstruction of the buildings, and Geographic Information Systems (GIS) (ESRI®) for the recreation of the terrain, thereby creating a realistic representation of what exists now, and a close approximation to what may have once existed.

In the second stage, a simplified version of the models was imported into a Virtual Reality (VR) game engine (Bethesda Softworks®) to create the ambience of the *villa* at the time, allowing full exploration of the space. It also includes fauna and flora, as well as Artificial Intelligence (AI)-driven avatars, as can be seen in the Video 1 provided in the electronic version of this manuscript.

1. Introduction to the project and research method

Today, Virtual Archaeology is mainly used for two purposes:

- as a means of dissemination (in VRML), usually associated with small objects or structures, where the user is invited to manipulate the objects remotely;
- as a tool for the reconstruction of objects and structures.

The first involves the visualization and manipulation of archaeological objects, a procedure quite widely used in so-called virtual museums. The second enables various theories to be tested. Suitable for research projects which aim to reconstruct buildings and environments that have disappeared long ago (Sanders, 2008). Despite all the subjectivity associated with this method of looking at the past (virtual), it is essentially an interactive method of inference in archaeology (Video 1).

It is usual to consider that the first virtual archaeological research results from applying Computer-Aided-Design (CAD) directly to 2-Dimensional (2D) drawings, because the digital format was potentially more reliable and allowed more accurate data; and the evolution to 3D occurred in accordance with the technological

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Video S1.

advances. However, processes for automatic data acquisition have also been developed that allow high quality results to be achieved in less time. Unfortunately, cost constraints have restricted their use to cultural projects of relevant social impact, such as the remarkable project of virtual reconstruction of Rome (Frischer, 2008). So-called minor projects (in terms of impact, but not culture) owe their existence to the spread of information technology and, above all, to the perseverance of professionals, acting as volunteers, who are always excited by the discovery of new objects as they delve more deeply into their studies, however small the site being studied might seem.

This is the case of Casal da Freiria. Although it was discovered in 1980 by Guilherme Cardoso it was only in 1985 that systematic excavations were begun, when the members of the archaeological team could dedicate themselves to studying the site.

This article describes the research, investigation and application of computational modelling to the virtual (re)construction of Freiria, and aims to:

- report on the systemization of procedures followed in situations where fieldwork data is obtained intermittently over prolonged periods;
- evaluate the potential of applying computational graphics programs to archaeological artefacts;
- facilitate scientific reconstruction through peer discussion;
- be a point of reference for future work of this nature.

1.1. Background

The interpretation of ruins is a topic which has sparked controversy since the considerations and reflections of Violett-le-Duc on heritage. The discussion, with no end in sight, was at least diluted when ICOMOS established the criteria for intervention. These have been published in charters[2] which mainly guide the physical reconstruction of cultural heritage. However, the apparent freedom that virtual tools offer in terms of being able to intervene in heritage has led to rules and standards being applied to them so that the resulting models can be used as research tools.[3] Interesting discussions have arisen about how these rules and standards should be implemented in archaeology so that they amount to what have been called 'knowledge representations' (Frischer and Stinson 2007, pp. 57). More projects of this nature are needed to overcome intuitive judgements of the team that is promoting them and to guide and stimulate active discussion of the topic.

There are countless advantages in turning to the tools which allow the recreation of virtual environments. First, the construction of a virtual model allows different hypotheses for reconstruction to be tried out without incurring the costs involved in a physical reconstruction, with the added advantage that it is both an interactive and a reversible process. Second, such a model is a basis, with which other, separate, items can be cross-referenced, even if they relate to other places or times. Furthermore, depending on the computer program used, additional information about the characteristics of these elements, such as alpha-numeric descriptors, can also be associated with them. The mere fact that they are digital items makes them a viable basis for remote work systems, which technicians can access when practical. In addition, they are the ideal tool when it is not possible to physically visit a site. Finally, a point to remember is that since they are easy to access and manipulate they are the vehicles of choice for multimedia publication.

The work in Freiria – a *villa* in a rural setting of the Roman era, dedicated to farming – can therefore be considered an experimental, immersive, archaeological study, developed in such a way as to adapt the usual techniques used in projects of this nature to the vicissitudes of a site only worked on sporadically for short spells, over a long span of time. The sequence of procedures undertaken to reconstruct the object of the study is described, using the field data collected by traditional processes and archaeological surveys. Then we explain the stages which led to the structure being modelled in such a way as to reproduce the existing state while preserving the quality of the data. Finally, we assess the hypotheses for

[2] Available at http://www.international.icomos.org/charters.htm.

[3] Available at http://www.enamecharter.org/downloads.html.

reconstruction offered by the participating specialists, distinguishing the various phases of the participations to provide peer discussion.

This paper aims to be a twofold reference: first, because it used accessible resources of both information technology and archaeological data to reproduce the model of a historic site, yielding results of very high quality; second, because it proceeds with the modelling according to established methodology for the recovery of cultural heritage which, because it allows the integrated and interactive consideration of data, provides a firm foundation for the results achieved.

1.2. Study object

The Roman *villa* of Freiria (central point 38°43′15.76″N 9°19′23.08″W, and at an altitude of 130 m) is situated in São Domingo de Rana (administrative area of Cascais, district of Lisbon) on one of the slopes of the valley near the village of Outeiro de Polima.

The site was developed around what may be termed a Manor House (*Domus*). Despite uncertainty as to the different usages of the various spaces and rooms, which is usual for buildings occupied over a long period (1st to 4th centuries AD), there is a zone in the surrounding area whose use has been identified as supporting farming. There are spaces for storing agricultural implements, oil and other presses, a granary and small rooms that were probably used to house farmhands. To the south are the remains of what are thought to have been spa installations (Fig. 1).

In the early stages of fieldwork the archaeologists prioritized the study of the remains to establish their importance. This resulted in an exhaustive study that nonetheless ensured the structures were subjected to the minimum of interventions, allowing them to be preserved in the environment in which they survived.

Thus, when in 1995 a complete survey of the structures was carried out, opting for the German method (Hauschild, 1988; Rodrigues, 1961), the main objective was to consolidate all the information already collected and correct problems which had occurred in the meantime with the on-site markings, specifically acts of vandalism by persons not connected to the excavation and which had destroyed the signs next to the oil press.

Fig. 1. The Freiria Complex: 1 – *Domus* – the manor house build around a central patio in typical Roman style. Infrastructure necessary for daily life, organized around a second patio consisting of: 2 – Storehouses, presses and annexes related to farm work. 3 – Rooms for slaves or farmhands; 4 – Spas; and, 5 – Granary.

The programme of surveys, which lasted until 2002, took place under the supervision of architect Pedro Sousa (then Assistant Professor of FA-TU Lisbon). The surveys were carried out in situ using traditional methods and provided information about how the structures were built. The plan consisted of establishing two orthonormalized axes which extended from the central point, using markers positioned to millimetre accuracy. These reference points made it possible to reproduce the existing elements on A3 graph paper on a scale of 1:20, with an accumulated maximum error of 2 cm, which is negligible.

The drawings were then converted to CAD format using a graphics tablet, after which these elements were georeferenced by means of GPS with differential correction through the cross-referencing of known points in the excavation, duly identified in the drawing, and the nearest geodesic marker (Trajouce trigonometrical station).

A full survey of Freiria was thus completed (Fig. 2).

2. Creating the 3D model using CAD

Even though the teaching purposes can be fulfilled using other types of technology applied to fieldwork, particularly 3D laser scanners, the reconstruction work based on pre-existing data was accomplished by specialists in the three main formats:

1 – Topographical survey (data to be used for the terrain);
2 – Archaeological survey (data to be used for the structures);
3 – Photographic survey (data on the configuration of the structures).

2.1. Topographical survey

Two topographical surveys were provided: one based on ordnance survey maps on a scale of 1: 25 000, (IGEoE, 1992), which covered a larger area but was less detailed, (10 m between contour lines), and the other, carried out at the request of the local Council, of a smaller area but on a scale (1: 1000) (CMC, 1975), which was in much greater detail.

2.2. Archaeological survey

The archaeological survey consisted of two files, one for each of the two phases of survey work in the field. The most recent resulted from the planimetric and altimetric surveys of the site, on a scale of 1: 20 and recorded all the elements as described in great detail. The other, which was the result of the earlier campaigns, contained the same type of information, but much more succinctly, on large expanses of structures on the excavation site, with general indications of the outline of the walls, the type of paving found and the possible use of each area.

Both files were then optimized to reduce the number of redundant elements. After this all data were compiled into a single file.

The CAD file was thus made up of the following layers (Fig. 3):

- topographical survey;
- archaeological survey (both planimetric and altimetric), with information on a scale of 1:20 (stone by stone);
- general archaeological survey (structural) with information on a scale of 1: 100 (outline of walls);
- general archaeological survey (non-structural) with general information such as the types of paving, location of the water supply system, on a scale of 1: 100 (ordered by the architect J. Bicho for the strategic plan of the surrounding area);
- excerpt from the 2 × 2 m grid used during fieldwork.

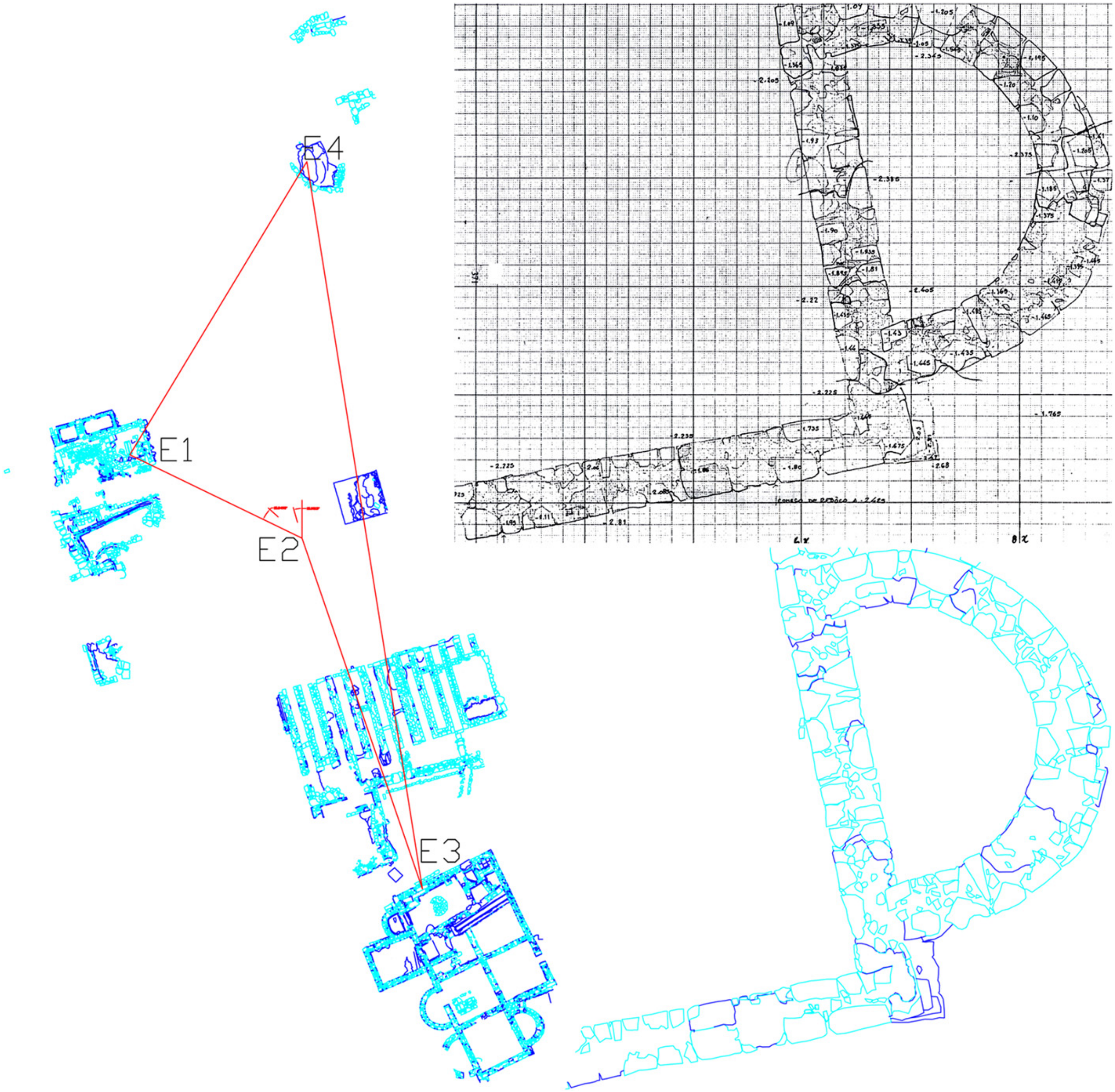

Fig. 2. An example of the survey procedure: the original reproduction and drawing of the whole with the 4 points used for georeferencing.

2.3. Photographic survey

The survey consists of a collection of photographs recording the excavations and soundings, taken by the archaeologist Dr. Guilherme Cardoso. Aerial photos of the area – perpendicular photos taken by the Portuguese Air Force (FAP-BA1, 1995) and oblique photos, mainly provided by the *Instituto Português de Cartografia e Cadastro* – were used as well.

The photos are extremely useful for work of this nature as they allow us to check all the details of the model which cannot be discerned by other means, details relating to the geometry, location in space and texture. This is what made it possible to later adapt the model to the particularities of the site.

With all the information duly compiled, the next stage was to import the two-dimensional information into the 3D modelling software.

3. 3D modelling

Anyone who has taken part in an archaeological campaign understands that sites rarely have a single well-marked 3-dimensional component. The space is read, mainly in a 2-dimensional form, with no observable support for the inferences being drawn. But it would be difficult to reconstruct it physically, either because of the cost or because there are so many hypotheses for the reconstruction of a single space, based

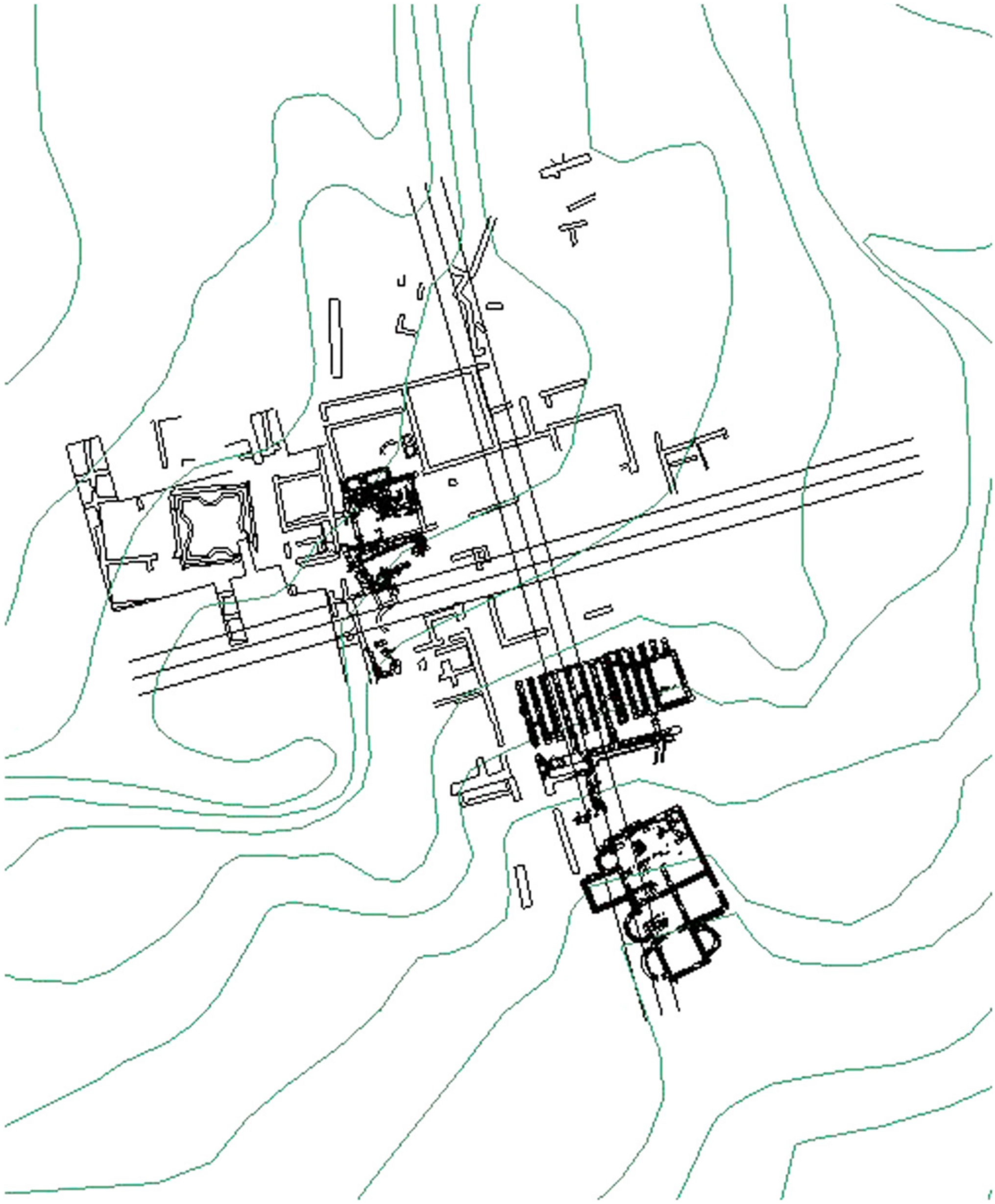

Fig. 3. An example of the layers used.

only on the discoveries as and when they are made on site. This is the main reason why 3D models and Virtual Reality programmes are particularly good for reconstructing sites – they allow different experiments and the analysis of the space on a human scale.

With the consistent recording of all procedures, computer graphics software may be exploited for archaeological research as a work-base which can be extended to other sites.

Thus, in order to allow different reconstruction hypotheses, it was decided that separate layers in the 3D model would represent its actual state and the different inferences which might be considered for that space.

3.1. Preparing the work files

The software 3ds Max (Autodesk™ 2008) was chosen because of its availability/affordability and because no extra training was necessary. Furthermore, it is compatible with the digital design format developed in AutoCAD (Autodesk™ 2008).

3.2. Creating the model of the terrain

The first object to be modelled was the terrain. The aim was to create a mesh to simulate the surface of the existing terrain, which would allow the position of any element to be determined easily. It was therefore necessary to replicate, to some degree, the grid used during the initial excavations.

The initial 3D model of the terrain was created using a tool from the 3ds Max (Autodesk™ 2008) software, itself called 'Terrain'. The result was a highly detailed and complex Triangular Irregular Network (TIN) grid.

After this original model a plan composed of 2 m square faces was created (Russo, 2005). All that remained to be done was to run the 'Conform' operation. This operation moves the vertices of

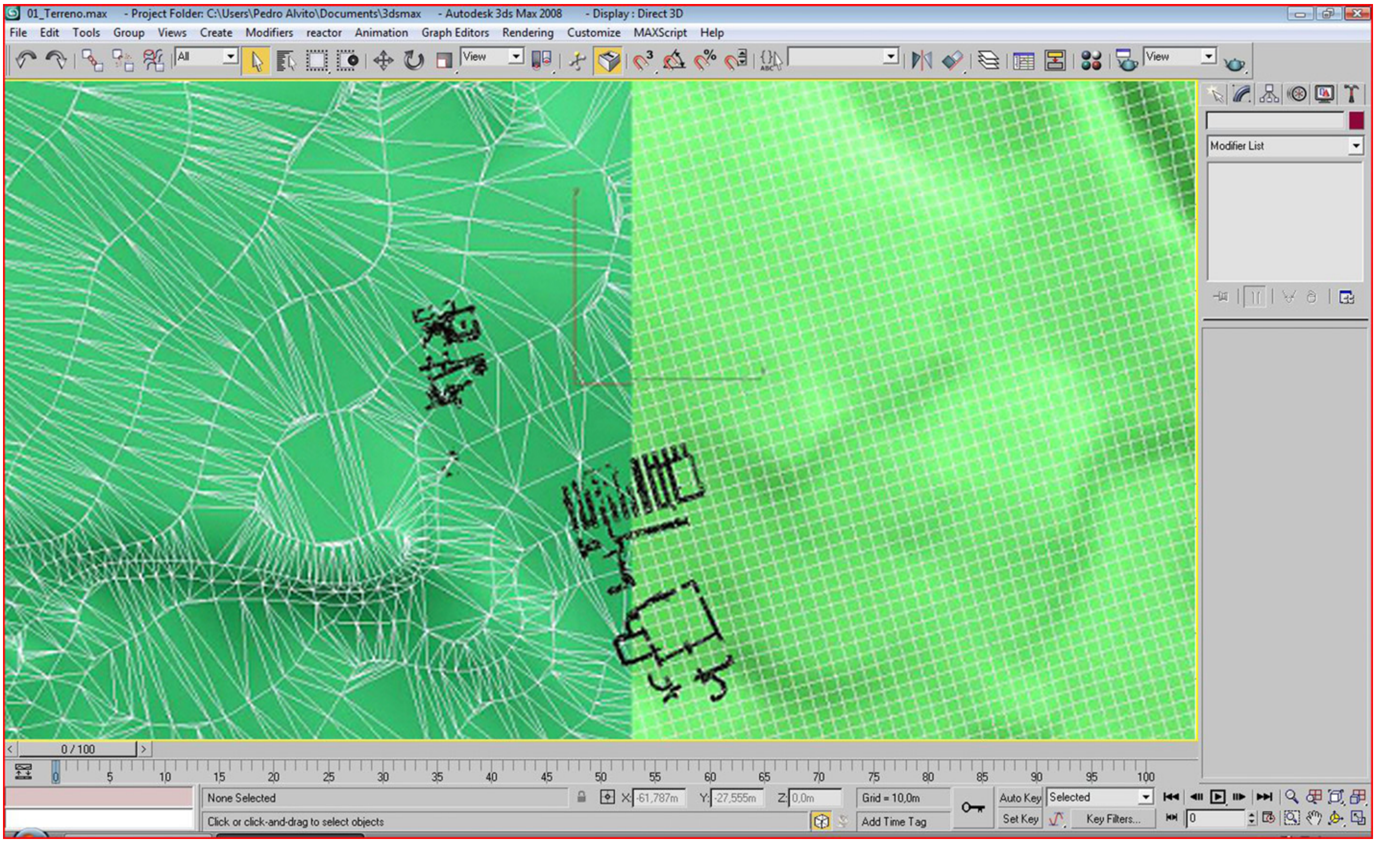

Fig. 4. The conversion of the topographic survey to geometry and the adjustment to the 2 × 2 grid.

one model until they collide with the surface of the other. The result is a mesh with the form of the terrain but composed of vertices set out on a 2 m square which coincides with the original (Fig. 4).

3.3. *Modelling the present*

The model of the walls uncovered during excavation is the result of the composition of two types of geometry and was derived from two archaeological surveys.

The detailed archaeological survey was for the most part composed of closed polygons, at different levels, representing the outline of the coping stones on the walls. Given that it was impossible to ascertain the exact configuration of each stone, and this was at any rate of little relevance to the present model, it was decided that a generic height of −10 cm should be assigned, corresponding to a negative extrusion, with the aim of keeping those elements in the correct position.

With the stones duly modelled, the archaeological survey was once again used to create the geometry of the walls for the height established for them.

Given that the topographical survey had not taken into consideration the alterations ensuing from the excavations, adjustments had to be made to the geometry by means of the subdivisions of the mesh (Fig. 5).

The actual state of the architectural structures and that of the terrain where they were situated were thus reproduced in the virtual model. Even though the files had been simplified to make the model easier to manipulate, scientific accuracy was in no way compromised: each object was in the correct position and correctly orientated.

This approach, though archaic and time-consuming, does have an advantage over present-day automatic data acquisition: when a global survey cannot be conducted the fieldwork allows filtering of the objects that should be included in a drawing which would otherwise have to be manipulated with appropriate imaging software. It also enables the information obtained in different fieldwork sessions to be combined and helps us to better understand the development of and changes made to building structures while they were occupied.

4. Reconstructing the past

To exemplify the reconstruction process, it was decided to focus the work on the granary since this was the central piece of the site and it offered the best chances of reconstruction.

From the previous survey it was possible to single out details indicating that the granary had been altered during its use, such having the foundations of one of the walls widened (Fig. 6).

This initial granary, with an area of about 123 m^2, had been enlarged by 35 m^2, which is why it was decided to reconstruct the building, as it would have been at the very end of its occupation period.[4]

Something else that was noticed was that the parallel arrangement of the walls, which allowed ventilation and airing, has been lost in the east and that the floor level is higher, which prompts the idea that this was the entrance area. And since no traces of the roof

[4] It is thought that in future these values will be used in a GIS model for the automatic generation of the land limits so that the inferences established for the site by the archaeologists (Cardoso and Encarnação, 1994), plus other socio-economic aspects related to this activity, can be compared.

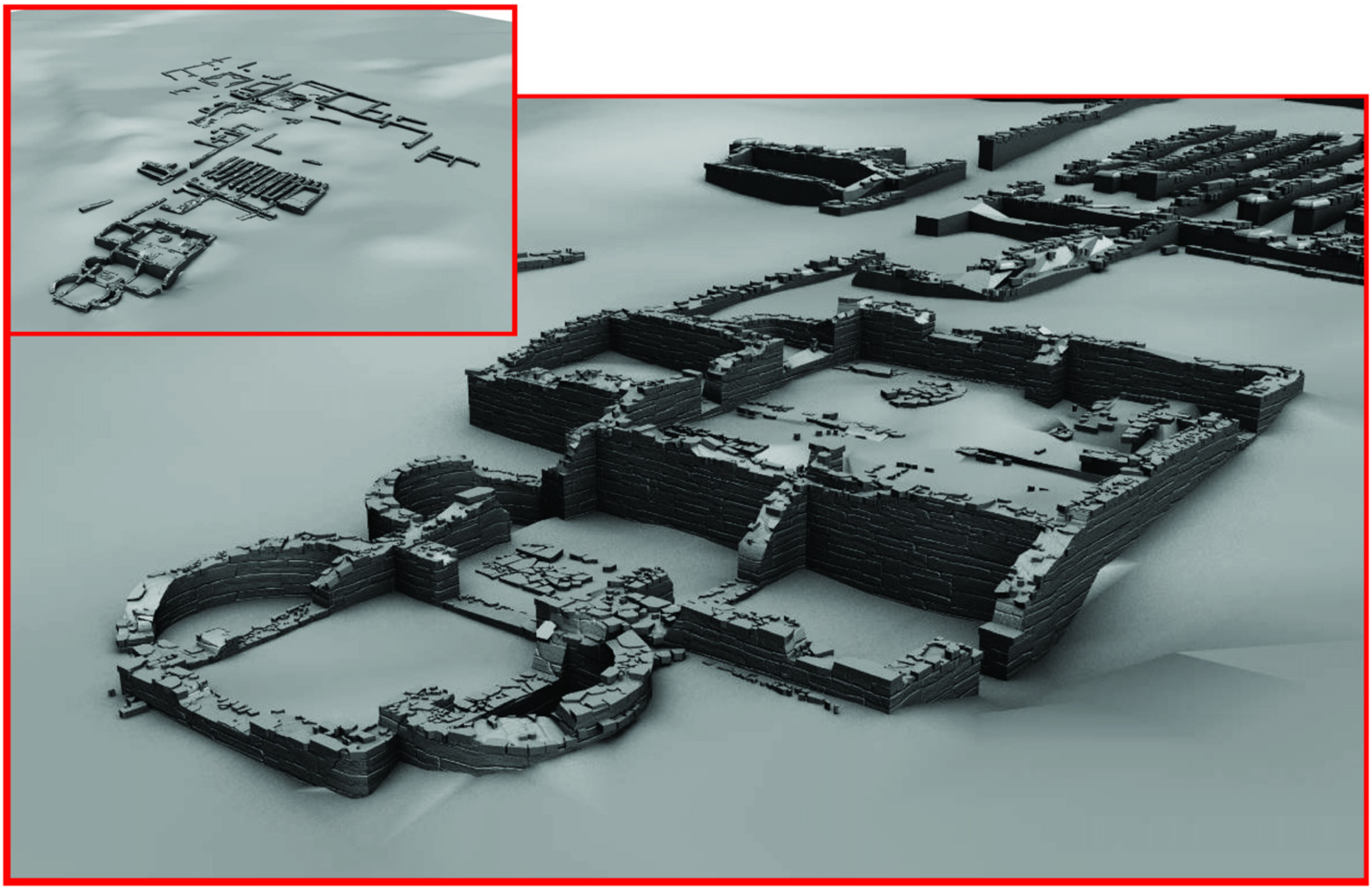

Fig. 5. Reconstruction of the present day archaeological site of Casal de Freiria.

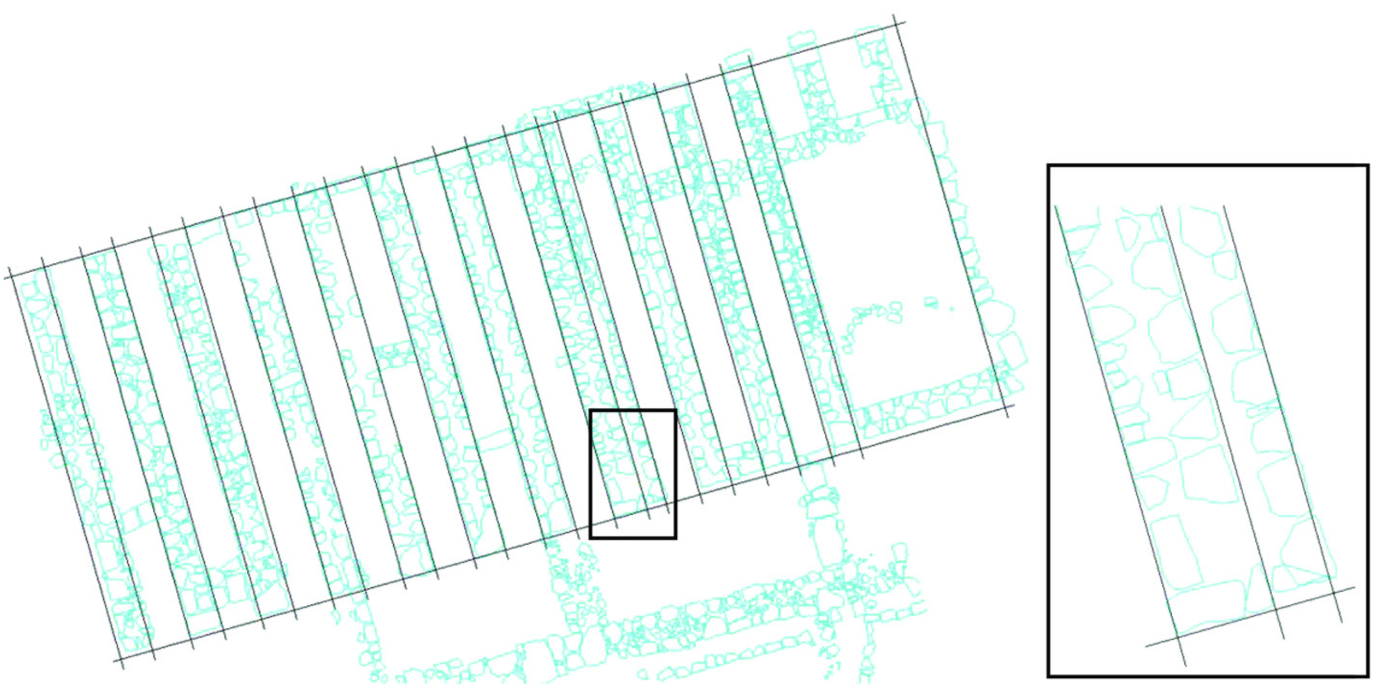

Fig. 6. Plan of the foundation walls of the granary and details of their reinforcement.

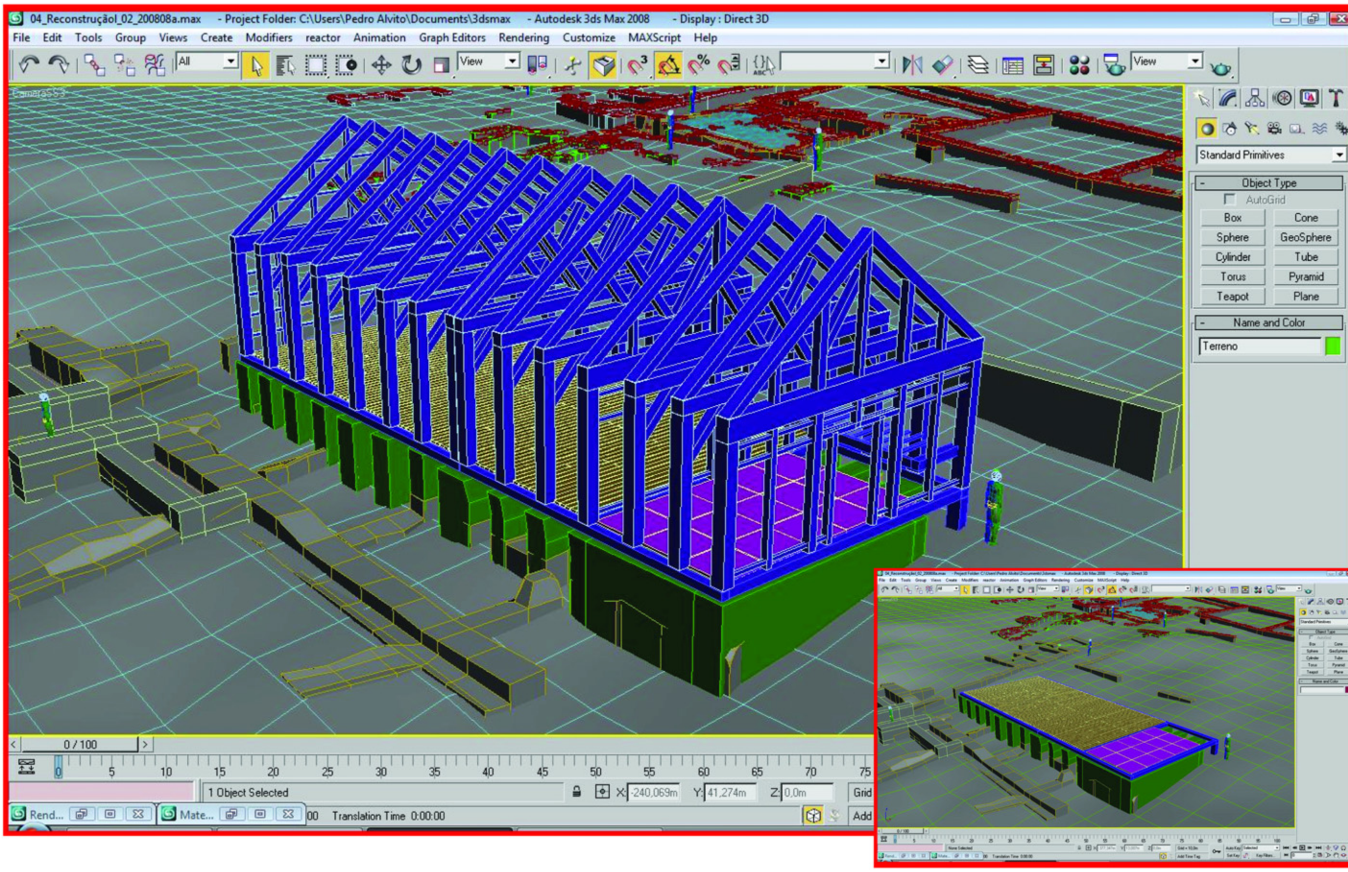

Fig. 7. Phases of the reconstruction of the Freiria granary, based on the existing walls.

or masonry were found, the idea that the walls and roofing were made of perishable materials seems acceptable.

4.1. The modelling project

To set the three-dimensionality of the proposed model on a firm footing, a comparison and analysis of the relevant literature was carried out (Alarcão, 1985; Macaulay, 1978), and discussions were held with archaeologists. The different hypotheses for the reconstruction could then be weighed and tested, and it was opted to develop the model as a wooden structure, clad with thatch and with a thatched roof (Bédoyère, 1991).

The modelling followed the expected order of a building process (Fig. 7). The foundations still existing on site were modelled first (Rua, 1998). Lying directly on the foundations and perpendicular to them was a substructure composed of wooden joists. This subsystem levelled and supported the main structure and the floor. The principal structure of the granary is a series of covered aisles which also define the slope of the roof. These aisles are above the substructure and have the same orientation as the foundation walls that support the full weight of the construction.

The side and rear walls, made of thatch, were modelled by creating a series of wooden support posts which join the aisles. The thatch panels created from the model of the plan are attached to the posts to simulate thatch hung on the posts. Only the facade of the granary, which is believed to have included the entrance door, was clad in wood.

The modelling of the roof began with the installation of the joists, supported on the aisle piers on which were set panels representing the thatch. To complete the model of the granary, structures were created for the shelves where the cereals would be kept, and for the ventilation holes which it was supposed would be needed to store the grain properly. The stairs leading to the granary were also modelled, since it was on a higher level and there would have to be some means of reaching it.

In the absence of any other indication, various hypothetical interpretations were proposed and the reconstruction models became feasible for the same base, the model having been prepared for this by separating what actually exists from what is proposed.

4.2. Post-modelling processing

After the modelling phase, the texture of the model had to be correctly assigned to make the scene more realistic and to distinguish between the different construction materials (Adobe® Photoshop® 7.0).

Each solid was textured in two steps: the different textures were first applied to texture maps[5] so that in the second step they can be correctly scaled and positioned using a UVW map.[6]

The model of the granary was textured by means of a set of texture maps applied to each of the objects and accompanied by the respective bump maps. Each map shows a different material that is suitable for the chosen modelling method. As each object only

[5] For further information please see: http://wiki.blender.org/index.php/Doc:Manual.

[6] For further information please see: http://www.escultopintura.com.br/Tutoriais/Tutoriais.htm.

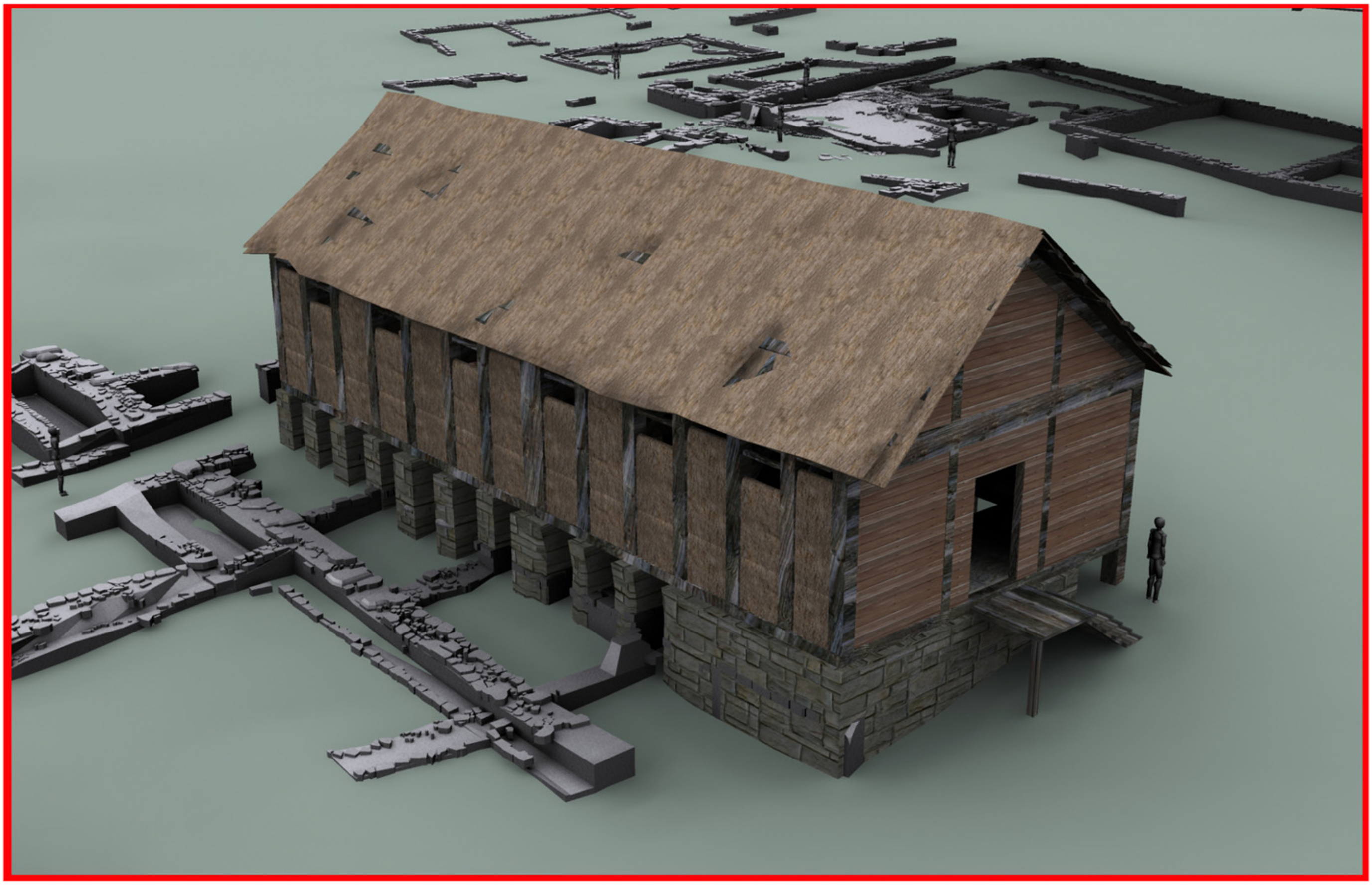

Fig. 8. Texturization of the Freiria Granary Model.

represents a single cladding material there is no need to create composite materials to deal with multiple textures.

This was the phase when the researchers were able to get a first impression of what the building would have looked like at the time it was in use, an impression which, in contrast to the characteristic horizontal nature of an archaeological site, points up the building's volume (Fig. 8).

However, the model is not dynamic: in other words, any alteration whatsoever, either in the execution of the model or in its visualization, is subject to complex and lengthy rendering processes which give absolutely no indication of what the outcome will be.

5. Virtual model

Information technology tools have made it possible to reproduce scenarios in an accessible virtual environment. But there are some limitations where the dynamic component of the graphics computer software is concerned, as it only allows the visualization of static images, and the slightest change involves repeating the same procedures for rendering (De Amicis et al., 2009). However, the uncertainty of the 3D component, so characteristic of archaeological work, requires the participation of the technicians to be dynamic and interactive and that the ability to communicate ideas should not be dictated by their tools: pencil and paper or bits and strings of instructions.

The choice of a game engine[7] for the representation of Freiria was the outcome of a logical sequence of procedures undertaken to achieve the virtual reconstruction of the archaeological site (Anderson et al., 2009), to overcome the limitation of the static display and allow a dynamic evaluation of the model. Care was taken, however, not to neglect the rigour of the information obtained in the survey phase, so that the occupation of that space at the time of its use could be determined in terms either of the image or of the experience (of living) in the space. It was interesting, too, to see how these procedures can stimulate the discussion of the rigour of the proposed virtual reconstruction.

The virtual model was imported using the map editor of the popular game engine (Bethesda Softworks®) which enabled the personalization of entities. The game runs on Gamebryo (Emergent Game Technologies, Inc.),[8] which is equipped with a high-quality graphics engine and a physical engine, AI, and software for the production of vegetation in real time.[9]

Another potential of this type of procedure – the customization of game engines (Grand and Yarusso, 2004) which supports scientific visualization (Bianchini et al., 2006) – and particularly of this software – concerns the creation of avatars with AI. The program already has a series of easily-modified AI scripts to define daily actions (to programme the slave-avatar to get up in the morning work in the fields and return home in the evening) or reactions to external stimuli (programme the guard-avatar who defends the *villa* in case of attack). It is also possible to define

[7] See: http://www.devmaster.net.

[8] See: http://www.emergent.net/en/Products/Gamebryo/.

[9] The customization of software is a widespread resource used in various areas of investigation. See: *Uma Ferramenta de Autoria* (Lima et al., 2004).

dialogues and reactions to certain dialogues in order to implement the subsequent phases of this project.

5.1. Importing the final model

The model has to be in the correct format before it is exported to the game engine. The file contains geometry data, collision geometry, texture maps, and links for their correct positioning, which have to be converted to a specific file.

It is very straightforward to import models into the editor. The user has to create a new object and indicate the location of the model to be used. The placing is a very intuitive 'drag-and-drop' style by which the object is dragged from a list to a scene.

The building of the remaining structure was only sketched in with the idea of creating the scenario of the era, essentially sheds for the tools and presses that were around the farmyard.

5.2. Creating the surrounding vegetation and AI

The introduction of vegetation is based as far as possible on the photographic survey and on the archaeologists' ideas for this area, as can be found in the excavation campaign reports and other publications issued between 1986 and 2002 by Cardoso and Encarnação. The software used has an extensive library of vegetation, with many types of trees and bushes, totally animated and textured, which certainly facilitates the process. Other objects, such as furniture and farm tools can also be added. The AI is implemented by introducing characters. These are models of humans which, apart from being appropriately equipped, can be edited to individualize their bodily and facial features; AI scripts can also be added to assign a set of pre-determined actions and reactions. The scripts can define simple actions such as going for a walk or complex actions amounting to a defined daily timetable, reactions to the surroundings or pre-defined dialogues.

In the case of Freiria, the interest in applying AI is that the numerous characters appropriate for the day-to-day running of a country farming estate can be created from whose analysis some inferences may be drawn, that is, some social arguments are developed (Heilig, 2001).

5.3. Integrating with the game engine

The visualization of the model is achieved through the game itself (Bastos et al., 2006), since the software acts as an editor of existing maps. The characters can move around within the game's environment using the standard keyboard/mouse combinations common to computer games.

For the first time in two thousand years it was possible to see Freiria, albeit in an incomplete form (Fig. 9). The interactive process allows the user to move around the space, analyzing the regularity of the distribution of the structures and considering the elements and natural relief of the locality (the terrain), and of the surroundings (the view). The hypothesis that has been presented is based on the existing structures. This means that it can be constantly updated, whether in terms of new data from the field which may be discovered in the meantime, or in terms of migrating files to other, more efficient software, linking them to make the scenario more and more complete.

6. Results and discussion

The main result of this work is that we learnt that it is possible to make high quality models using tools available to any user and data common to the majority of archaeological sites. The modelling described may be a point of reference in the use of computer graphics tools for the interactive study of the unwritten past. Thus the reconstruction of Freiria was not limited to a static visualization of the space but was able to create an inhabited historic scenario which users could manipulate.

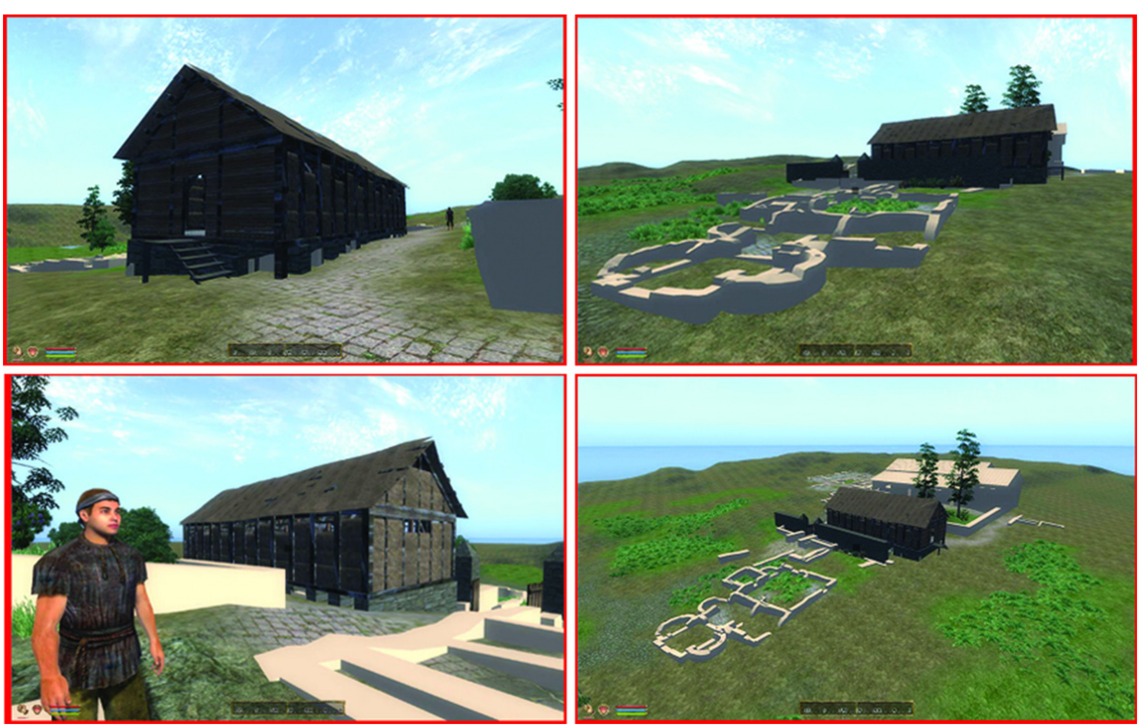

Fig. 9. Freiria: examples of interaction with the virtual space.

Fig. 10. Models showing the different hypotheses for reconstruction and the expanse of the structure still needing a solution.

The success of the modelling process also prompted discussion about the composition of the team to see if other areas of expertise should be added to the range of disciplines: any research is enriched by the participation of specialists in different areas, which in our case include architecture, structural engineering, animation and 3D modelling. The way in which the data from the site were integrated made it possible to guard against any loss of rigour in the conversion of information by suitably adapting the model to archaeological research. However, producing a highly complex model to meet strict scientific standards has the important drawback of being hard to manipulate, because of the amount of information associated with the files.

There are several ways of dealing with this from dividing the model into different files with cross-referencing between them, to simplifying the geometric and statistical summary or even customizing a game-card The low-cost representations are excellent means of publishing information (Koutsoudis et al., 2008), although the reduction of information may very well generate changes which could inadvertently become an integral part of the model, altering the whole story that it tells us.

This is why the model was only simplified after the theories about the site had been established, so that the subsequent phases of study could be adapted to the original, pre-simplification version.

Having a model that is better suited to real-time manipulation means that technicians can visualize and experiment with different theories and hypotheses for reconstruction (noticeable in our project), whose 'use' enabled the space to be considered interactively in accordance with the theories of each specialist. In addition, the results could be compared in real time.

One example of this concerns the configuration of the entrance area of the granary; it is the most consensual in terms of location since it is an unventilated zone above the floor, but, despite several attempts it is not yet absolutely satisfactory, principally because (Fig. 10):

- the absence of a foundation wall means that the last truss must differ from the others, since if the whole structure is made so as to prevent problems from rising damp, there is no logic in standing one of the joists on the ground;
- the entrance could make better use of the natural downhill slope of the ground in order to make the access more level, and therefore more convenient and, so it may have been positioned next to the corner of the north façade of the granary;
- or this depression may be a means of access which takes into consideration the loading and unloading of grain from ox-carts.

Whatever the truth, it was only possible to question these hypotheses after visualizing and experimenting with the place, which brought to light the need for further data input before any firm conclusion can be reached. This again highlights that the model was constructed deliberately to enable updating whenever a theory needs to be tested, without it having to be completely reformulated.

7. Next developments

In the future, it would be interesting to be able to test the application of automatic surveys, such as 3D laser scanning and white light scanning, on the archaeological site, even if only on small stretches, and compare the results with those presently obtained by traditional survey techniques, free of their connotation as instruments of the past.

Apart from the speed of acquiring data, the use of automatic equipment has the advantage that information is already in digital format, so the errors from data conversion from analog to digital to which traditional drawings are obviously subject, is reduced to a minimum. However, an important issue is emerging both because of the creation of remote access platforms that can be used by researchers into the same topics through sharing on wiki-sites, thus allowing efficient and rapid inference (Web3D Consortium, 2006; The Elder Scrolls Construction Set Wiki; Kimer et al., 2001), and because more and more (simplified) models are available on the Internet, which offers a means of publication and of interactive experience of information. The issue is that these processes are so popular and so sought after by consumers that the present demand for models and instruments adapted to their needs makes their creation imperative (Hartman and Wernecke, 1996).

The use of a game engine to recreate the scene, providing high quality graphics and environmental elements (vegetation, physical consistency of objects, and AI), plus intuitive editing commands, enables us to affirm that this was the right decision to help us to attain the initial objective: Living the Past.

The use of a virtual scenario in a game engine as a means of experimenting with inferences allows the user greater involvement than exclusive software offers, plus the possibility of customizing (Champion, 2004), thus the present model can be exploited even more. Establishing a population that uses the space and provides indications of the *pars rustica* boundaries (Gutierrez et al., 2005), about which so little is known at present, is an example of what users might achieve, which is a positive contribution to a new way of studying history.

Finally, subsequent to this initial contribution applied to archaeology,[10] it would be useful if this technology were available

[10] http://www.civil.ist.utl.pt/~hrua/Ensin/FreiriaFilme.wmv, available on: 2010/10/08.

in the near future in a widely accessible version, either in Open Source (ARTLab®, 2006), or in 3D Open Platform (Slusallek et al., 2009), for both the modelling and interaction tools.

8. Conclusions

In archaeology, uncertainty is a certainty. For this reason, fieldwork demands procedures based on a highly intense methodology, however irrelevant a find might seem, "as if in order to succeed in remaking the site, if this were possible," (Leroi-Gourhan, 1950). What is being proposed here is the application of the same scientific procedures to new computational modelling and graphics technologies.

The fact that the automatic processes of data collection in the field were not implemented, and that available information of a great degree of technical accuracy was used, meant that rules could be established which could be used as references in similar cases, or on sites which have disappeared for some reason, or are an advanced state of dilapidation, where only previous graphic elements can be accessed.

In spite of the constant uncertainty which surrounds archaeological research – mostly there are simply not enough data for a definitive conclusion – in the case of Freiria, the collection of records of its remains, spanning centuries of different occupations, meant the space could be reconstructed, which resulted in the first view of the building as it would have looked to those who lived and worked there while it was in use. The subjectivity surrounding these issues was not ignored; the model was developed within its own context, but clearly highlighting the distinction between reality and inference. In other words, taking the real site as a basis, the virtual granary was literally constructed, with wooden beams and slats clad with thatch, under the constant technical supervision of architects and archaeologists.

The fact of having focused the reconstruction project on a building – the granary – which at the outset seemed such a consensual choice, does not mean that the model entirely satisfied the opinions of all the experts involved; the matter of the entrance has still not been entirely elucidated. However, the way in which the information is structured ensures that experimentation and discussion can be supported by the model, so that hypotheses can be tested as they are visualized and their feasibility can be assessed. All of this would otherwise have gone unnoticed if traditional graphic recording methods had been used.

With Freiria, we are proving that inferences or working hypotheses give better results when implemented in 3D environments than in static 2D drawings, as this new approach provides a rapid means of experimenting with and visualizing ideas. This shows that it is a suitable procedure for discussing, sharing and disseminating information about an object, a city or a whole civilization. It can therefore be stated that 3D models are far more than a simple medium for exhibition: they are quite definitely fundamental to archaeological research, and are therefore a new way of looking at history.

Thus, we believe that we have far exceeded our initial proposals, going further than the mere production of a model by establishing a whole sequence of procedures adapted to archaeological modelling. Discussion on this topic within the scientific community has thus been encouraged, and this exposé offers an example for future developments.

Local investigation showed the experts the importance of Freiria. The on-site campaigns were intermittent, undertaken every August from 1985 to 2002, and eventually the local people were drawn in; they learnt a little more about the historical importance of the site from their participation, and also came to play an active role in protecting the site. Without these campaigns it would have been abandoned and left to disappear, which is the fate of the vast majority of cultural heritage sites. This is a particularly delicate issue in cases where no records have been made.

The greatest changes wrought on that site since it was last occupied, two thousand years ago, are due to the consequences of urban expansion ensuing from the growth of the population of Lisbon and neighbouring municipalities. Freiria was an integral part of the local urbanization plan, therefore local people were aware of the importance of the find and the gains that could accrue from the integration of the ruins into the Strategic Plan for the area. So there was an unusual convergence of factors in which retrieving the past was fundamental to the overall preservation of the monument, in the present and the future.

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