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Reconstructing Roman Archaeological Sites: Theory and Practice—The Case of Conimbriga

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Abstract

Recent work on the virtual reconstruction of a Roman town is presented, in the context of issues like conserving, presenting and communicating that cultural heritage to the general public. Reconstructions are developed using manual and procedural techniques, with the support of efficient and low-cost tools, using the internet for collaborative and dissemination purposes. This paper also intends to discuss general issues of the extent of scientific knowledge and the authenticity of communicated products.

Keywords

Virtual Heritage, Procedural Modelling, Virtual Environments, Conimbriga

1. Introduction

Ever since the Renaissance, people have looked to ancient sites, namely Roman, and have wished that they can be seen "as they once were".

The paradox of the "ruins of the Empire" both in its metaphysical, political sense and in the factual remains of once mighty works of art and engineering is a powerful driving force behind historical and archaeological research, cultural tourism, heritage management and, generally, public awareness and communication of these issues.

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The situation of the matter is one of taking decisions that please, on the one hand, the yearnings of the public and, on the other, the concerns of specialists involved, both from the archaeology and art history field, who generally are concerned with plausibility, authenticity and scientific accuracy issues, from the technology field, where feasibility (both in production and in communication) is the main concern.

This paper approaches all these issues taking the Roman town of Conimbriga (Roman province of Lusitania, currently Portugal) as a case-study using the World Wide Web as the means for it dissemination.

Conimbriga was first excavated in 1899, and systematic excavations began in 1930. From this moment onwards, the Portuguese state acquired the land and the site was open to the public, quickly becoming the major archaeological monument in the country. Having exposed a major focus of interest, the mosaics of four major residences, excavations subsided in 1944, but the site museum was inaugurated in 1962 and excavations resumed in 1964. Until 1971 the new excavation project progressed with great success and the major monuments of the town were identified [1]. Publication of the findings was carried on until 1979, when the museum was being remodeled (to be finally open to the public in 1984).

The interest of the public has kept visitors number (on average) around 130,000/year, for these last thirty years, but obviously the demands of those visitors have changed dramatically over the course of a generation: a virtual reconstruction is one such evolving demand and a major concern behind this paper.

Conimbriga is today excavated in some 15% of its extension in the imperial period, when it attains 22 hect. [2] (**Figure 1**).

In the excavated area, half a dozen of public monuments (baths, the forum) and thirty-odd domestic buildings are known in plan. The elevations of all these buildings, though, are very poorly preserved [3].

Of course, the preservation of the buildings is far from what is known in the Vesuvian area, but the problem goes deeper than that.

The fact is that, even in public monuments, the degree of preservation is feeble, due to successive sacking and reuse of stone.

Accordingly, reconstitutions can be made plausible; this happens in particular with buildings offering a demonstrable vitruvian project [4]-[6]. But reconstructions cannot be proposed as accurate, because the evidence for them just isn't there to be used. In full earnest, outside those buildings, like the forum, where the intervention of a vitruvian-educated architect can be deduced from the plan of the building, we have good reason to doubt the "Romaness" of architectonic traditions of the town [7]. Why indeed should we expect the architecture of Conimbriga to conform to classical norms when it is quite clear that its urbanism does not?

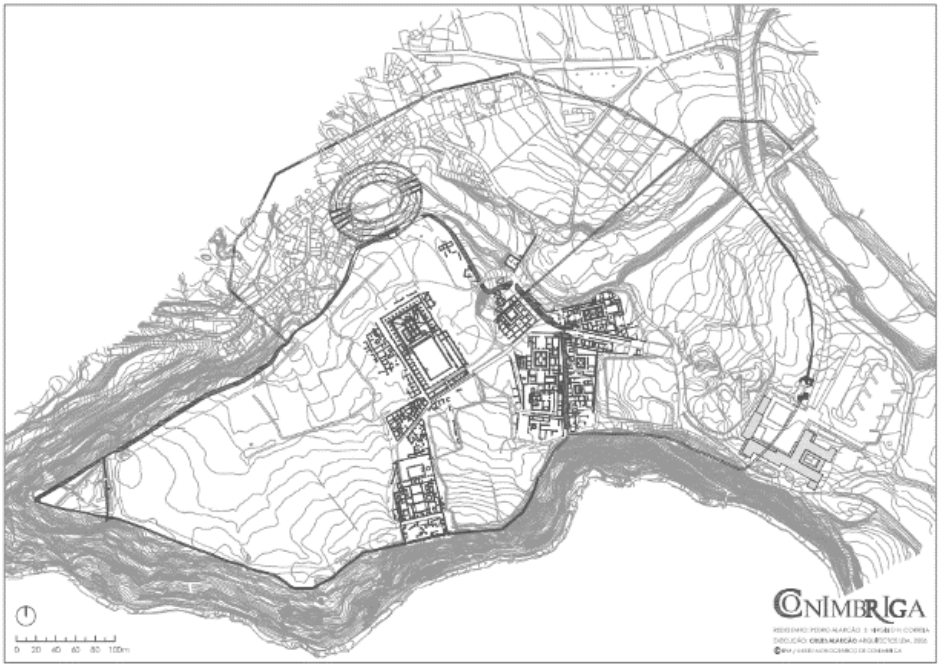

Figure 1. General plan of Conimbriga.

2. Reconstructions: A Theory of Practice and the Practice of Theory

In its essence, the problem is that from a strict epistemological perspective one has to recognize the fact that, in most specific cases one cannot scientifically support a particular reconstruction as an alternative to another one, on the basis of given elements or data. The arguments for or against any individual solutions just are not there to be tested against facts; they depend solely on empirically chosen examples, "models", with no subsequent capacity to evaluate the relative merit and appropriateness of the solutions, architecturally speaking.

An additional aspect of this problem is the disproportionate importance of the scale at which the reconstruction is proposed:

Ideally, a theoretical reconstruction of a building ought to be able to be critically assessed and judged "right" or "wrong" (the issue with the use of inverted comas in this instance shall be addressed further in this paper) at any scale, be it 1/1 or 1/100 or 1/1000. Actually, that is not the case, and especially not so in traditional media reconstructions (paper, maquettes, etc.).

One can propose magnificent ideas and images at 1/1000 that are "untranslatable" to more detailed scales [8] (**Figure 2**). Size allows for critical observations and reveals voids in our knowledge that can be masked at larger scales by an advantageous use of human perception limitations.

One problem with digital reconstructions is precisely the fact that being in principle at least-independent of scale (the same is to say that they are all produced at scale 1/1, regardless of the scale at which they are actually seen), they force us to address the true extension of our knowledge of the architectonic evidence and the merit of our theoretical reconstructions, with no scale gimmicks to hide our ignorance or inability to reconstruct what was built.

The theoretical questions just briefly discussed here raise a first practical question: are they (the theoretical questions) relevant to the general public and should they be conveyed to it as part and parcel of the reconstruction that we (archaeologist, heritage managers and ICT specialists working on a particular site) are communicating?

Our (of the present authors) answer is yes, and the project we designed aims at incorporating it in model recon-

Figure 2. An essay of visualization of Conimbriga at the beginning of the II c. AD, by J. C. Golvin [8].

structions of Conimbriga as a means of assuring authenticity to the public. This is supposed to be the dividing line between an archaeologically informed reconstruction of a specific Roman town which is managed by a dedicated public institution (the site museum) and, for instance, a scenery for a Roman-inspired video game; we do not intend to deny at any length the right of the latter to exist, but the distinction between one and the other is, in our view, to be made clear and recognizable and indeed, our experience shows that a large part of the public appreciates the possibility of distinguishing them [9].

The whole issue of the authenticity of reconstructions is an important one that crosses the line between the theoretical and practical questions and with it arises another subject: how do we convey our reconstructions to the public?

We shall leave aside the theoretical aspect of this subject; we shall not dwell on the legitimacy of reconstructing something time took charge of demolishing, neither shall dwell on the dangers of misrepresenting the actual finds and leave them in a minor role facing the glamour of reconstructed reality.

The economy of experience—something society at all levels craves-supersedes these considerations. But technical considerations do have a role cut for themselves in the interplay of actual remains and reconstructions.

In Conimbriga, the forum itself is a good example. The main construction moment is also the one whose reconstruction was least subject to scientific criticism is represented in a 1/500 maquette [10] (**Figure 3**) that has, since 1986, been one of the most successful pieces of the exhibition in the site museum (that means more than 3 million people have seen it so far).

One wished the maquette could be displayed on site, but it can't. We must fulfil our wishes with a limited 1/1 maquette of the most essential scale-explaining elements placed on the actual remains [11] (**Figure 4**) and that has been criticized as overreaching!

On the other hand, the forum of Conimbriga has been the subject of projects of virtual reconstruction that have met with general appreciation, amongst other qualities for its light-weight and ease of interoperability [12] [13]. These digital instruments, however, are not immediately accessible on-site to the general public and the widespread use of portable devices, will always leave a margin for questions of inequality of access to be put forth in the discussion of these themes.

3. The Proposed Solution

Since the work presented on the forum more recent technologies have emerged to represent 3D content over the internet, VRML is now replaced with more recent technologies such as WebGL [14]. This means that no longer specific plugins are necessary since recent browsers are capable of natively run these technologies. Furthermore WebGL has hardware accelerated capabilities.

Often most virtual models over the internet are produced manually in authoring tools and then exported to a 3D format. This workflow is however costly, due to the significant price of often utilized 3D authoring tools and to the time necessary to manually produce the models. For such reasons, in recent virtual reconstructions of

Figure 3. The maquette of the forum of Conimbriga at the site museum.

Figure 4. The forum of Conimbriga, with recent work.

Conimbriga structures, such as "House of Cantaber", the "House of the Apsidal Medianum" and the "House of the Trident and of the Sword", a low-cost alternative to the classic manual modelling process has been addressed [15] [16], towards the production of highly detailed virtual models, by using open source software and a low-cost moving depth sensor.

Still, on more vast environments (e.g. an entire Roman heritage city) sometimes it is impossible to determine what existed in some places. Take the example of the heritage site of Conimbriga where a small percentage of that ancient was brought to the surface. Even when more information is available, hand modelling (through the means of 3D authoring tools) all the structures typically involves significant use of manual reconstruction techniques, and thus a great deal of human effort.

Often, there is not sufficient physical evidence to recreate these structures precisely as they may have been in the past.

However, sometimes there is no need for detailed models of all the structures in a city, simply because they will not be shown for some reason (e.g. will not appear in a video).

To address these issues domain specific modelling methods for automatic generation of virtual heritage structures were also utilized in Conimbriga [17]-[19]. These methods are guided by heritage knowledge about the construction rules of heritage structures, encoded in a formal grammar, and may be used to create new structures automatically.

The ambition is the dissemination of our cultural heritage legacy, making it accessible, not only to experts, but also to the general public, without requiring any high performance hardware, authoring software or professional 3D skills. For visualization, our virtual reconstructions will be available through a three-dimensional live model viewer, based on recent technologies such as HTML5 and WebGL. Those may be triggered from a wide variety of devices, contributing in this way to a true democratization of history knowledge.

Taken all this considerations into account a workflow process was defined, illustrated in **Figure 5**, which is composed by three major steps:

- Modelling
- Artefacts and furniture
- Web publishing

As can be perceived the whole process accounts with the collaboration of experts in ancient Roman Archaeology [20]. Indeed, the whole process was conducted by expert knowledge to produce plausible representations of structures for which only the ruins subsist. This include drawings of the initial floor plans, the definition of roof structures, the definition of each area types of the house, the choice of materials, furniture and artefacts, amongst others.

This is an iterative process since after presenting some results to experts the need for changes often arises. This is indeed one of the worthy assets of having 3D reconstructions, where some less correct assumptions about the possible representation of structures, are only detected when examining in detail the digital models. Although this could be done with physical more traditional representations the fact is that the efficiency and flexibility of computers in this task is undeniably an advantage. Furthermore, since 3D printing are becoming available at

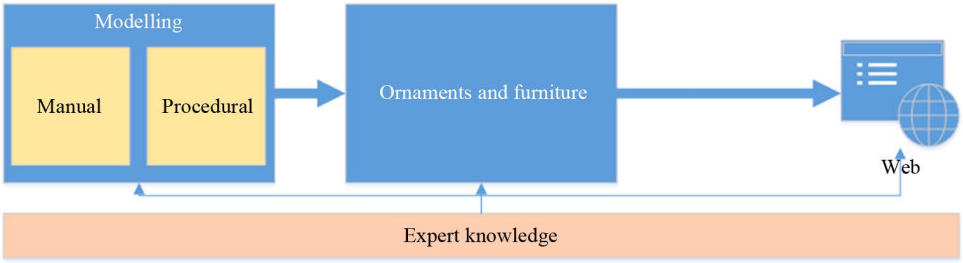

Figure 5. Development process workflow.

affordable prices, this also arises in some cases the temptation to print some of these models. As a matter of fact, for accessibility purposes this is becoming more often, allowing people with special needs (e.g. visual difficulties) to have access to heritage knowledge.

Although the steps which compose the workflow are presented generally, on their own they are made of several additional steps. In fact the modelling stage includes the creation of the structures geometry (e.g. walls, floors, roofs, etc.), but also includes the application of colors, materials, textures, amongst others. Additionally it also takes into account several design choices associated with the architecture of each house, such as the type of columns (e.g. Jonic, Tuscan), number of floors, type of each room (e.g. cubiculum), etc.

3.1. Modelling

Considering that only about 15% of the heritage site of Conimbriga was brought to the surface, two distinct approaches were taken to deal with the virtual reconstruction:

- To use manual techniques to reconstruct the structures within those 15%, for which enough information is available
- To generate the remaining structures using procedural modelling techniques

Hence they are referred to as “Manual reconstruction” and “Procedural approach” correspondingly.

3.1.1. Manual Reconstruction

At the moment five houses of Conimbriga were manually (digitally) modelled:

- The Forum;
- House of Cantaber;
- House of the Apsidal Medianum;
- House of the Skeletons;
- House of the Trident and of the Sword.

Although the modelling was done manually, one of the main goals was to implement a low-cost and efficient workflow to achieve some accurate results. For this reason the modelling was done with Blender [21]. This is an open source 3D authoring tool, still with most paramount features found in other commercial software.

The modelling itself started from detailed plans of the houses, from which the walls are extruded to the heights provided by experts in Roman Archaeology. Similarly all of the floors and ceilings were created. Then, if present, the corresponding elements of the houses are added (e.g. columns, *impluvia*, etc.). Finally the roof structure is created (**Figure 6**).

To complete this basic modelling, several materials were applied accordingly to each feature of the house, including textures attained from preserved real mosaics from Conimbriga’s houses such as the one presented in **Figure 7**.

3.1.2. Procedural Approach

The procedural approach aims mostly to recreate the area of Conimbriga that is unexplored. The idea is not by any means to replace the manual approach, but to provide a tool for rapid generation of structures (at this stage only houses).

As for the time being these models still do not have the proper historical and archaeological fidelity to provide correct hypothesis over the possible faithful reconstructions of Roman heritage cities, nevertheless they still have several possible uses. For example, in a historic context, to provide alternative scenarios to possible city

Figure 6. Virtual (manual) reconstitution of the House of Cantaber.

Figure 7. A Conimbriga mosaic representing the "Labyrinth of Crete with the Minotaur".

configurations. In other scenarios they could be used in other like entertainment such as digital games or cinema, in movies related with ancient Roman civilizations.

The reality is that the mixture of manual and procedural generated structures may be exploited together with computer graphic and cinematographic techniques. This allow the production of videos where the scenes can be specially organized to focus mostly on the structures created manually and have the procedural ones in background, where most of detail are not visible.

The method used for the automatic generation is guided by a grammar which encodes several rules to automatically create the structures, either by heritage knowledge composed by a heritage construction set of rules (Vitruvius [22]) together with Expert rules (rules inferred from experts on the particular case study) or by specific rules declared by an expert user (User rules). The overall method architecture, described in detail in [18], is

shown in **Figure 8**.

Structures are then translated into geometric models which are then complemented with suitable materials and textures.

At the present moment only basic geometry of the houses are being generated, *i.e.* the houses do not include any type of artefacts or furniture. This procedure allows the later inclusion of manually made models from a 3D object database. For example, it is possible to include manually modelled columns and, using the grammar, to set them to be distributed in an Atrium. One example can be seen in **Figure 9** where a procedural version of the House of the Skeletons is shown.

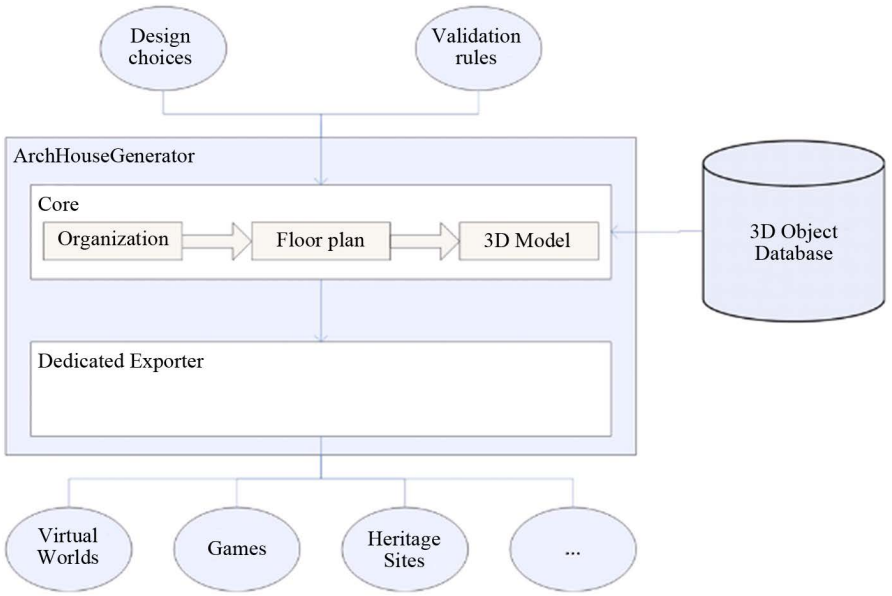

Figure 8. A procedural heritage generation architecture.

Figure 9. Procedural version of the house of the skeletons.

3.2. Artefacts and Furniture

To represent a house it is not strictly necessary to have artefacts and furniture, nevertheless this are of great value to improve the experience of visualizing it, since it give the feel of a human presence. Also an important goal for including these objects is to help perceive the function of each room of the house. For example, if we see a kitchen ware it may possible to be a *culina* or even a room with a social function such as a triclinium.

In order to attain further goal of the modelling phase, *i.e.* provide a cheap expeditious approach to develop different artefacts originally used by natives, we used a Microsoft Kinect. Despite of it primary use (gamming), the Microsoft Kinect is a depth sensor that consists of an infrared laser projector combined with a monochrome CMOS sensor. This low-cost laser scanning equipment is perfectly suitable to rapidly get a 3D model of an object. The objects utilized from the Conimbriga heritage site were attained with the support of the Kinect Fusion [23], an Application Programming Interface (API) from Microsoft which provides the scanning capabilities. This allows automatic creation of the corresponding 3D models, from laser scanning data, which may then be exported to a common format which may be easily edited in a 3D authoring tool. **Figure 10** shows some of these objects before they were edited in Blender.

This edition is due to reduce its geometry complexity and any kind of abnormal geometric deformations are corrected, making it appropriate for web publishing. Similar to the previous modelling step, adequate materials and textures are applied to all of the artefacts and furniture.

To increase the realism, these objects are used both in the manual modelled structures as well as in the procedural generated structures.

3.3. Web Publishing

Apart from providing these cultural heritage virtual reconstructions to a wider audience through the web, in this kind of ancient virtual reconstructions it is essential to provide efficient means to allow the whole reconstruction process to be guided by an expert. This feature is of extreme importance since sometimes it is not feasible to have local contact between the modelers and the consultants (or even possible evaluators of the final models). So, the possibility to have models which evolution may be tracked is appealing. This feature also allows for broader tests to be conducted since the models may be widespread for larger audiences and collaborative knowledge platforms implemented.

Until now we were constrained to the use of specific browser plugins to access 3D content [12] [13], which

Figure 10. Two examples of Conimbriga acquired artefacts.

did not natively included several realistic computer graphics features such as shadows and reflections. Nowadays, the scenery has changed with the advent of HTML5. Indeed, the latest browsers support WebGL [14], a JavaScript API which makes it possible to render interactive 3D content in compatible browsers without plugins. Furthermore it also allows code to be executed on computer's GPU. Additionally, in order to allow experts to interactively navigate through the models Three.js [24], a lightweight 3D Javascript Library, was utilized. This library includes a Blender plugin which makes very practical to export 3D models into a webpage.

4. Testing the Extent of Our Possibilities

Moore's law [25] states that computing capacity doubles every two years. From the technical point of view, hence, the solution of our problems will be given by time itself. The solution to our basic problems, however, will not. We must address issues of authenticity and availability germane to the reconstructions we draw.

We are indeed drawn to the perspective first (and foremost) enunciated by the Polish poet Janus Vitalis (*De Roma*, 1554) in a Latin sonnet widely glossed, quoted and copied:

> "*You search in Rome for Rome*? *O Traveller*! *in Rome, itself there is no room for Rome, the Aventine is its own mound and tomb, only a corpse receives the worshipper. And where the Capitol once crowned the forum, are medals ruined by the hands of time*; *they show how more was lost to chance and time than Hannibal or Caesar could consume. The Tiber flows still, but its waste laments a city that has fallen in its grave-each wave's a woman beating at her breast. O Rome*! *From all your palms, dominion, bronze and beauty, what was firm has fled, what once was fugitive maintains its permanence*" (*Robert Lowell's* [1917-1977] *translation of a Spanish version of Vitalis' poem by Francisco de Quevedo* [1580-1645]).

Ultimately, what we want and need to convey, and what indeed society expects (we think) is a sense of the flux of time in all its glorious, or infamous, but mostly tragic consequences.

We shouldn't be dwelling on the fictions of a "presentist" reconstruction of a lost golden era of perfect urban entities of days gone by. Generally speaking, the marble city of Augustus is the same slum where Juvenal, Catulus and Seneca lived. Its demise was not entirely a misfortune, at least in what hygiene, sanitation and some aspects of social behavior are concerned.

That is why our reconstructions need to be as accurate as we can make them, transmitting all aspects of past ways of living we can reasonably reconstruct, in a way that must be easy to access and equally easy to incorporate the progress of knowledge and the context of its perception. The public, we hope, will be able to retain from that an idea of the lost monuments, but also a sense of communion with the people that lived in the town we're reconstructing (or Vitalis' Tiber).

5. Conclusions

We can produce reconstructions of ancient sites virtually to the full extent of our imagination. We can rest assured that what we are unable to do today will be possible in the future. The relation of cultural heritage sites with the yearnings of an ever more sophisticated public is hence assured via ICT's applications.

But the work that we continue to seek in order to (virtually) recreate this piece of our cultural legacy, cannot answer the main questions independently. Collaborative work between the technical side of the question and the heritage agents is an essential part of the positive response in the public, in all its various configurations.

That is the line of work we will be pursuing.

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