An Approach to (Virtually) Recreate Historical Findings

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Abstract

The use of technologies in the preservation and dissemination of the Humanity historical and cultural heritage has become an increasing reality. However, access to some of these projects, namely those involving the use of Virtual Reality techniques, is often rather restricted and limited due to technical specificities used in its development and/or visualization. Availability to the general public, for instance through the Internet, becomes, then, impracticable.

VRML (Virtual Reality Modeling Language) emerged from the desire to project World Wide Web to a new level, the three-dimensional level. However, even though there are not many alternatives, VRML is not used often. In fact, the number of projects available that use this language is lower than expected. Why? Generally the development of realistic VRML environments results in a set of big files that difficult its download. The complex calculations often necessary to display the virtual environment also create difficulties, since they demand too much for low end computers.

This paper intends to present some VRML optimization techniques that allow the creation of a very low file size and a realistic historical environment that can be accessed from any current personal computer.

As a result, you can make your own historical tour at:

- The Flavian Forum of Conimbriga: *http://www.forumflaviano.web.pt*
- House of Skeletons (Conimbriga): *http://www.casadosesqueletos.web.pt*

Introduction

It is widely recognized that information and communication technologies can have an important role to play in archaeological settings. Virtual Reality is an expression normally used to refer to a set of different technologies that can be used to create interactive virtual environments that represent three-dimensional surroundings, real or not, present or past. This type of representations can be used in different settings, but Archaeology is one of the most obvious possibilities.

Some more sophisticated Virtual Reality technologies demand the utilization of special hardware and software which seriously difficult its utilization in archaeological settings. The cost and knowledge involved aren't usually available in museums, for example. However, other VR technologies do not demand

specialized hardware or software. For example, QuickTime VR panoramas and Virtual Reality Modeling Language (VRML) environments need only a web browser and the right plug-in to be displayed.

Historical settings reconstruction, especially of those that doesn't exist any more, is one of the most interesting applications for VR. It is not difficult to find in the web projects of this type. History Virtual Tours (BBC, 2005) and Virtual Gettysburg (Gettysburg, 2005) can be mentioned as examples.

VRML is an interesting option for this type of projects, since it allows publishing the environments in the web, making them available to any person without the need of any special hardware or software. The only requisite is a free VRML plug-in. Moreover it is possible to achieve a reasonable level of realism. However, many VRML projects result on lengthy files, which seriously difficult its download and utilization by many users. This is particularly evident in more complex environments, such as real scenes, past or present.

The idea behind this work was to develop a VRML representation of two of the most important architectural scenarios of the roman civilization in Portugal: Conimbriga's Flavian Forum (Gonçalves, Mendes 2003) and the House of Skeletons (Silva, Gonçalves 2004), also in Conimbriga and, at the same time, to test the viability of the working method used in the first project (The Flavian Forum), now applied to an architectural scenario (House of Skeletons) significantly different, not so symmetrical, from the first one. As we wanted to allow its utilization by any interested person, there were two often contradictory requirements: It was necessary to create a realistic environment that could show how the "buildings" really were, but we needed to keep the environment file size and computational complexity as low as possible, so that there weren't access difficulties. The result of this project can be appreciated in *http://www.forumflaviano.web.pt/* (Flavian Forum of Conimbriga) and *http://www.casadosesqueletos.web.pt/* (House of Skeletons).

We believe that resources like these have a significant social value. In our case, our environment allows archaeologists and historians to observe the monumental aspects of the architecture used by roman civilization. Together with other resources it can support several types of archaeology investigations and promote a deeper knowledge about the roman civilization, its architecture and way of life.

The total file size of the VRML reconstructions is less than 150Kb (the Flavian Forum) and 300Kb (the House of Skeletons) and its runtime computational complexity is also low, allowing its utilization by any person, even not using a broadband connection or a last generation computer. These good results where achieved due to the utilization of several optimisation techniques, without any concession in terms of historical realism.

Case Studies

The Flavian Forum of Conimbriga was built between 75 and 80 AD, in one of the biggest and most prosperous cities of the Roman Empire in Lusitanian territory, the city of Conimbriga. Like most Roman forums, the Flavian Forum was an imposing and grand monument, both for its size (96m x 48 m) and for its architectural refinement, one of the most emblematic and representative areas of the old city of Conimbriga. Today the Forum and the entire city are in ruins and are practically destroyed.

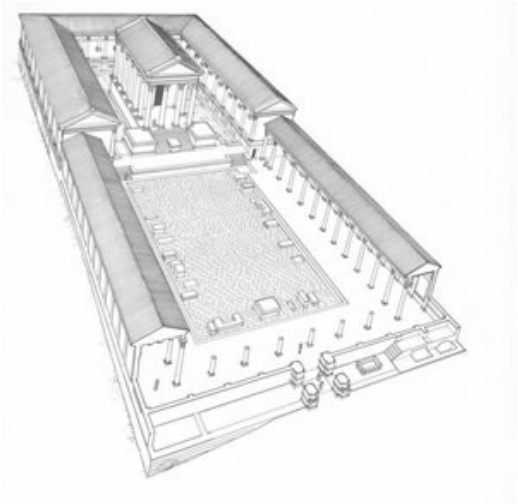

Fig. 1 Conimbriga's Flavian Forum

In its reduced dimensions (945 m2) the House of Skeletons (the name came from historical factors) can be taken as a paradigm of the residences of quality of Conimbriga: quality of the architectural plan, economy of means, emphasis in the ornamental program of the mosaics, intelligent use of the autonomous part of the construction. The analysis of the house comes across, though, with some inherent difficulties because the façade was destroyed by the construction of the late-imperial wall.

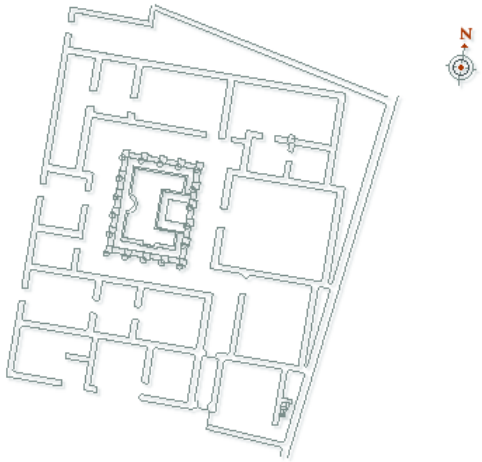

Fig. 2 House of Skeletons plant

The main objective of the work described in this paper was to allow everyone to enjoy an interactive visit, albeit virtual, to these representative settings of the Portuguese historic and cultural heritage.

In order to do this, we prepared a three-dimensional recreations, as accurately as possible (from the number of steps, the size of the stone slabs, patterns, colours, number of columns and correct positions, etc.) and to the real scale of these disappeared places.

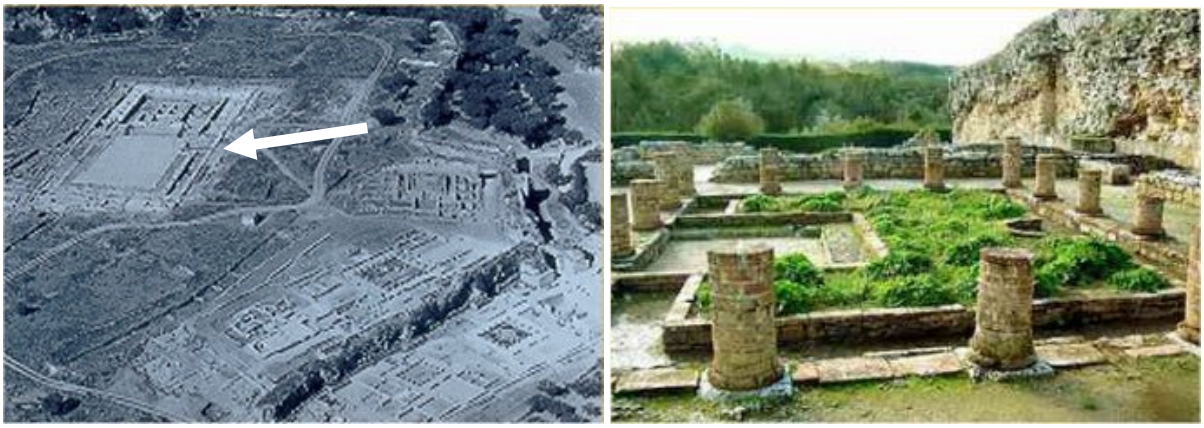

Fig. 3 Ruins of the Forum (left) and the House of Skeletons (right)

The technology

Having in account the characteristics of the project and the main goals, the technology to use should have the capacity to achieve good visual results, but at the same time to supply the author the necessary potentialities to carry out an efficient development. The Virtual Reality Modeling Language (VRML), is a language that allows the development and publishing of virtual environments on the Web. It as it's own syntax and generates a simple text file. There are, although, native VRML development tools that generate the VRML code (like an HTML editor). In our case, we use Cosmo Worlds 2.0 from Silicon Graphics.

Optimisations

In a purely technical analysis, this is the most important key point of this kind of work as the optimisations used were crucial for the results obtained.

We will, then, present some of the most important optimisation aspects implemented in the development of both projects.

Cloning

Instead of using the sometimes inefficient *copy/paste*, VRML enables the use of instances of any of the existing geometric forms in the scene. This property is extremely useful as it avoids the unnecessary duplication of code, re-using the properties of the object already defined.

This was one of the most frequently used techniques in the development of both projects.

In the Forum there are several geometric patterns that repeat themselves. The copy of each of these patterns was obtained precisely with this technique. For example, the wall of the left corridor follows a specific geometric pattern, as we can see in figure 4 (left). We only had to make a model of one of those patterns (figure 4 - right) and from it obtain the rest of the corridor.

Fig. 4 The corridor (left) and a piece of the modelled corridor (right)

After concluding the left corridor, we realized that the right corridor was identical, with a 180º rotation followed by a translation. As a result, the whole left corridor, which was already made up of several clones, was itself cloned to create the right corridor.

This technique can also be used in objects geometrically similar, but with different dimensions. Optimisation becomes possible, even where apparently it may not be. An example of this is shown in the following figure. The small object placed at the beginning and the centre of the grand staircase of the temple is a clone of the left side podium.

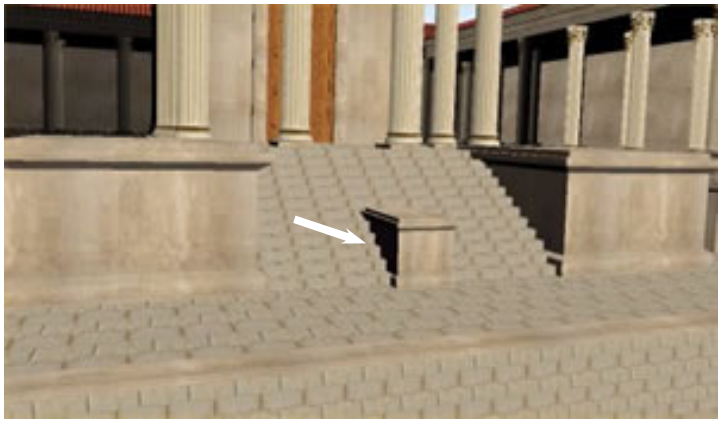

Fig. 5 Object cloned using a different scale

In the House of Skeletons, all the walls of the house were built based on blocks to whose were applied translation, rotation and rescaling that allowed to adapt it to all the other walls. The walls around the garden were also built based in one only object, that once changed, allowed the elaboration of the kitchen step.

The column is another object where the cloning advantage is clear. Only one column was modelled, the others were achieved by instancing. This allowed significant gains on the performance and size of the file, because the geometrical characteristics of the column are far from being simple.

Fig. 6 Columns achieved using instancing

The roof with the two waters structure (excluding the tiles plane) it was also reproduced with the resource of clones, it was not totally applied because of the rescaling compromised the aspect of the tiles.

Collision

As they are carried out in a three-dimensional space, the collision tests are generally heavy. To simplify this process, we implemented two measures using the properties of VRML:

- Disable the collision tests of surfaces with which it is not possible to collide. As the user is only allowed to “move” gravitationally through those areas, he will never collide with many existing surfaces, as for example the roofs.
- To simplify the collision tests we defined less complex geometric shapes, like simple primitive forms, to be used in calculating collisions instead of original and complex forms (therefore generating heavier calculations). Through this method there is a significant reduction of tests to check the possible collision between the “user” and any solid surface. Whenever possible, this procedure was used. In figure 7 we can see an example of this: the whole base of the portico (in the Forum), marked white in the drawing, is made up of large number individual “parts”. However, collision tests are carried out on only one simple parallelepiped that covers the whole of its area.

Fig. 7 Simplifying the collision tests

Textures

The importance of textures in the final work leads us to deal carefully with this item. Nevertheless, and whilst realism is fundamental, textures may have a negative impact on the global performance of the system due to their dimensions. Therefore, we need to optimise it as well.

- Use textures to simulate complex structures that otherwise would need hundreds or thousands of polygons to represent them. Despite the several cases in both projects, the one that presented the greatest difficulty was the Corinthian column's capital of the Forum;
- All textures have been treated in order to have a good relation between size/quality. For instance, in the Forum, many of them do not exceed 2KB, but this is not visible in the general quality of the virtual world;
- In order to economize in the size of the textures, some of them have been treated so that they can be displayed in a mosaic. Two of the best examples is the slabs in the square of the Forum (figure 8 left) and part of a mosaic of the floor of the House of Skeletons (figure 8 right).

Fig. 8 Tiled textures

- Using the same texture, and without having to load a new one (ones) to the memory, we can achieve different visual effects, only by changing some characteristics of VRML. There are some examples of this situation in both works.

Billboard

Although the VRML essentially has the vocation for the 3D, it also allows the use of bidimensional objects. The use of these objects it is inclusively recommended to increase the performance or the realism. For that purpose we use the billboards. These association nodes allows us to show the associated objects always in a frontal position for the user, independently of its position in the world, resorting to rotations over a certain axis.

Analysing the functionalism of a billboard it is possible to conclude that they are advised to represent symmetric objects, whose observation from different angles won't have major variations.

In both projects, the use of the billboards was just reserved for the columns. Due to the mould of the column and to the considerable number of columns that it was necessary to present, this object was the right one for the use of this technique, considering its symmetric aspect, its resemblance in all the visualization angles and the use of a texture for its representation.

In order to improve realism, we applied the *billboard* on a curved surface. Starting from a cylinder with neither base nor top, and "cutting it in half", we used one of the halves to apply the texture and to apply the *billboard* as well. Visual improvement occurred at two levels:

- As lighting calculations are applied to a curved surface, the effect produced is superior;
- Visualizing the column, especially the area of the capital, provides a more realistic effect if applied on a curved instead of a plain surface.

Fig. 9 Effect of the *billboard* applied to the columns

Number of Polygons

During the modelling of all the parts used in both projects, we were very concerned with the number of polygons. However, the reduction in their number should not damage the realism significantly. Therefore, and once again, it was necessary some sort of balance between the realism of each part and the number of polygons necessary to represent it. Sometimes we achieved quite a significant reduction in the number of polygons, without implying a reduction, in the same proportion, in realism.

For example, the model of the Flavian Forum has approximately 17000 polygons. Apparently, and as almost the entire volume of the Forum is visible right from the beginning of the visualization, this number would be intolerable for a fluid movement, particularly when using equipment without major graphic potential. This does not happen due to the optimisations made during the development of this project.

Simple Primitives

As the VRML browsers have been optimised to represent simple primitives (cubes, spheres, cones, cylinders and parallelepipeds), these primitives have been used whenever possible to model the different objects, even when not necessary. For example, in the Forum's walls of the temple's porticos, as well as the temple itself, are just boxes (parallelepipeds). However, there were other more complex objects that were "constructed" using simple primitives, either by intersecting them or by their adjacent position. For example, all the existing effects in the doors were achieved through the adjacent position of parallelepipeds with distinct dimensions (height, width and depth).

However, the use of intersecting/overlapping the parallelepipeds has also been used. For instance, with the exception of a small part, the podiums of the Forum were obtained using this technique (figure 10 left). These are two examples:

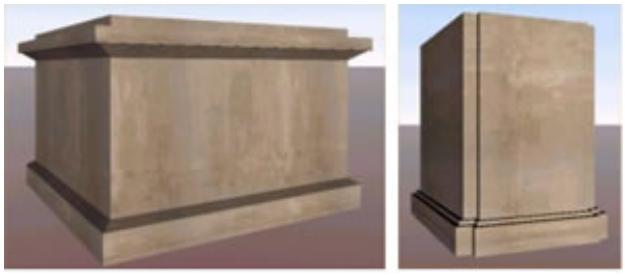

Fig. 10 Parts built by intersecting simple primitives. A podium (left) and a ornament at the entrance of the Forum (right)

Hierarchy

A VRML file is established by nodes. These nodes may contain other nodes, that by its turn it may contain other nodes and so on. This type of organizing files indicates the use of a hierarchic structure. The concept of hierarchy on a VRML file has to do with the way how the objects that constitute the virtual scenery relate between themselves.

One of the tests made by the browser through the representation of a virtual world, is the test of visualization (culling), that is to say, verifying which objects are completely out of the viewing volume of the user, so it can be determined which ones are visible at the moment. The test consists in intersecting the viewing volume with a representative bounding box of the object and if those two volumes don't intersect, we conclude that the object is not visible, therefore it can be ignored through the rendering of the scene (Silicon Graphics 1998). As you can imagine, this intersection process of the volumes is a heavy calculation in the internal processing, because it implicates very accurate mathematical calculus, at a three-dimensional level.

The all process can be simplified and optimized by defining a hierarchic structure for the objects disposition, in the way that the visualization tests start to be done just by the bounding box of the node that it is on the top of the hierarchy that can, and must, contain several associated objects.

In this work we can see the whole file as a hierarchic structure, in which each node includes other nodes.

- The larger volume objects were divided in smaller objects to turn its representation more optimized in the virtual world.
- The objects were assembled by its proximity, as we can see in the following figures:

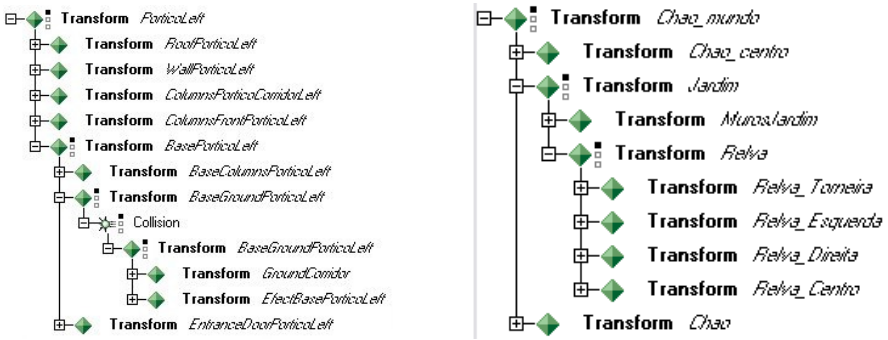

Fig. 11 The hierarchic structure stated in the Cosmo Worlds (Forum-left/House of Skeletons-right)

In virtue of the used structure, the mathematical calculi made and related to the bounding boxes were reduced, maximizing the optimization.

Compression

Presently, the majority of VRML *browsers* offer the possibility of unpacking from the gzip format in real time, enabling the immediate visualization and reading of the packed file without any difficulty.

In our case, the compression process was very simple as the working tool (Cosmo Worlds 2.0) has a command that completes it automatically and with no major difficulty.

Main characteristics

Here are some of the main characteristics of this work:

Realistic Model

As mentioned before, the virtual model is a realist representation (and up to scale) of the original buildings. It gives the possibility to visit them in the perspective of an inhabitant of that period, and thus have

a real perception of the colours and forms of the architecture of the ancient Roman Empire. Simultaneously, from that same perspective (about 1,70m high), it gives the visitor the real magnitude and impressive surrounding areas, especially in the Forum.

Interactivity

Another main characteristic of this work is its interactivity. We created a virtual space where the visitor (the user) can have complete autonomy of movements in the area of the Forum and the House of Skeletons, which means, she/he can go where she/he wants, following the path she/he chooses, just using an interaction device (keyboard or mouse).

The visitants of these virtual spaces can take advantage of an important characteristic of virtual worlds elaborated in VRML: it is very easy to use. Simply by pressing the directional keyboard keys or clicking and dragging the mouse, any person will be able to move in the virtual space without any difficulty. All the movements are made trying to give the visitor a realistic perception of what would physically happen in a real visit, such as the notion of climbing stairs or falling off a high place.

Guided Tour

We also created versions with a guided tour that goes through all the areas of the monuments. The idea is allowing the user to visit them without having to manipulate the mouse or the keyboard to control the movements.

File Dimension

This was one of the main achievements of this work. Due to the optimisation techniques used in both projects, we were able to obtain a very small total file size. For example, the main, and only, VRML file that generates the Flavian Forum of Conimbriga has approximately 22Kb and the total file size (including textures) is lower than 150Kb. The House of Skeletons VRML file has 17Kb. It is possible to store both virtual representations in a small and obsolete floppy disk, and practically without losing any of the realism obtained.

Performance and accessibility

Still due to the optimisations made in the development of this work, the performance of these virtual spaces is fully satisfactory in any current domestic equipment. Often, performance in low end computers is a complex problem, since the runtime processing necessary to view VRML worlds is too much for those computers. That doesn't happen in our case due to the optimisations introduced in it.

Accessibility is also a problem in many virtual reality projects. Many times special requirements in terms of hardware and/or software seriously difficult the access by all people interested. In our case the only condition to view the work is an Internet connection and a VRML plug-in installed in the computer. This makes it widely available to any person and, especially, to archaeologists and historians interested in the roman civilization.

The Flavian Forum of Conimbriga is available at: *http://www.forumflaviano.web.pt*.

The House of Skeletons is available at: *http://www.casadosesqueletos.web.pt*.

Cost of the project

This is a type of work that is not very expensive, financially speaking, in contrast to others with similar objectives, namely the conception and the time required to implement it or the tools to make it possible (in VRML), where, for instance, all the applications needed to the visualization are available for free.

Even after its conclusion, it is possible to make improvements to the realism of the recreated space, without any alteration in the VRML file. For such, a simple improvement of the textures used in the scene, automatically updates the visualization.

Conclusion

The last years have confirmed an increasing concern, mainly of important institutions such as UNESCO or the European Union, with the preservation, interpretation and spreading of the historical and cultural legacy of our ancestors. Such fact originated a new wave, where the use of new technologies, namely Virtual Reality, has a larger role to play.

The Flavian Forum of Conimbriga and the House of Skeletons was the basis of the work presented in this paper, which aimed to recreate with accuracy, in a virtual way, these impressive but disappeared monuments. Other main goal of these projects where to test the viability of a working method. The results produced indicate that they are perfectly reliable to make other kind of (virtual) “reconstructions”.

Moreover, this work allows any interested individual to contact with the characteristics of these disappeared monuments. In particular, we believe that archaeologists and historians will find this resource valuable to achieve a better understanding of several aspects of the Roman civilization. The interactive three-dimensional representations allows a deeper contact, better than any drawing or written description.

In this kind of (virtual) work, other fundamental issue is the optimisation of VRML “code”. This requires a deep awareness and spending some time developing a project using this language. But once acquired, we can achieve amazing results with developing times similar to others technologies.

To conclude, with a little perseverance and some care in the design, especially in optimisation, we will be able to develop good VRML projects. Moreover, this is a cheap, easy to use, interactive, works in any home computer, independent from the platform and, amongst other features, it is world wide accessible.

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