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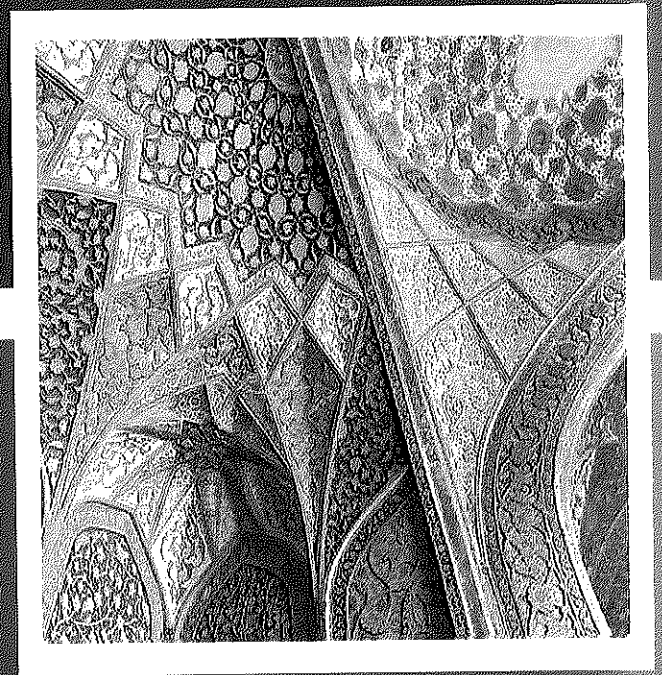
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Digital Media and it's Applications in Cultural Heritage



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Reconstruction of Ancient Rome in Interactive Virtual Reality

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Abstract

The "Plan de Rome" of Caen (France) is a large plaster model of nearly 70 square metres which represents ancient Rome in the 4th century A.D. Classified in the Inventory of Historic Monuments, it is the work of the architect P. Bigot (1870-1942), winner of the Grand Prix of Rome and professor at the Ecole des Beaux-Arts in Paris. The Plan de Rome is an exceptional piece of our cultural heritage whose only equivalents are its twin which is in Brussels (Belgium) and the model made by I. Gismondi which is in Rome (Italy). Bequeathed to the University of Caen, this relief plan is the pretext of a pluridisciplinary project for a virtual 3D model. Work on developing a virtual model of the city of Rome in the 4th century A.D. began in Caen in 1994. The work involves the development of a fully interactive model of ancient Rome that includes both its architecture and the machinery in use. In reconstructing the past, scholars will be able to test their assumptions from the architectural and topographic viewpoints and test machine functionality. The visitor to the virtual model will be able to wander through a full-scale city and enter most of its large public monuments and a few residences. The work preliminary to the reconstruction itself involves the analysis of ancient source materials, which is currently being performed by the project team's members who have recourse to outside experts for help with specific points. The body of source material is directly accessible via the interactive model. This paper discusses the history of the project, its methodology and the problematic of the reconstruction of an entire city in interactive virtual reality.

Keywords: *virtual Rome, interactive virtual reality, research, public at large.*

1 Introduction

Ancient Rome has always fascinated, in particular, western people. Reconstructions have been increasing since the Renaissance: literary reconstructions (e.g., Flavio Biondo's *Roma Instaurata*, 15th century – Raffarin-Dupuy, 2005), drawings and watercolours (e.g., *Les envois de Rome*, 19th century – Pinon & Amprimoy, 1988), physical models (e.g., P. Bigot's and I. Gismondi's monumental models, 20th century – Royo, 2006; Liberati, 2003). Today digital techniques offer new possibilities for reconstructing the past (among the recent writings, see Vergnieux, 2006; Frischer & Dakouri-Hild, 2008; see also the international colloquiums of the CAA - *Computer Applications and Quantitative Methods in Archaeology* – www.caaconference.org – and, since 2003, the biennial colloquium "Virtual Retrospect" organised in Bordeaux by R. Vergnieux). Many scholars around the world are working on ancient Rome (e.g., in Italy the project "Virtual Rome" - Pescarin, 2008), but only two teams are rebuilding the entire city, in its condition as of the 4th century A.D.: the team "Rome Reborn" at the University of Virginia (USA) (Frischer & Dylla, 2010) and the team "Plan de Rome" in the University of Caen, France (Fleury & Madeleine, 2009). The two teams signed a joint venture agreement in 2008. The University of Caen is fortunate to own P. Bigot's physical model and since 1994 the team "Plan de Rome" has been developing a virtual model. In this paper, we will explain how this project was born and how it has evolved. There are many differences between virtual reconstructions such as what we made in the 1990s, with pre calculated videos or Quick time VR, and what we have done since 2003: developing an interactive tour of the city with dynamic access to the metadata. The first question we will answer is why we have chosen interactive virtual reality. What are the limitations imposed by this choice? After speaking of the methodology, we will visit a sector of imperial Rome: the Campus Martius with the theatre of Pompey and a street with flats and shops. Then, we will explain how we can make an interactive tour of the entire city of ancient Rome, with a progressive loading of the model and with the main buildings modelled in different levels of details.

2 The Beginning of the Project in the 1990s

2.1 A Reconstruction: Why, for Whom and How?

The pretext of the work is a seventy square metre model of ancient Rome made at the beginning of the 20th century, and known in French as the "Plan de Rome" (see fig. 1). It is a plaster model which represents ancient Rome in the times of the emperor Constantine (4th century A.D.). Classified in the Inventory of Historical Monuments, it is the work of French architect P. Bigot, winner of the Grand Prix of Rome and professor at the Ecole des Beaux-Arts in Paris. The Plan de Rome is an exceptional part of our cultural heritage whose only equivalents are its twin which is on exhibit in Brussels and the model made by I. Gismondi in Rome. Bequeathed to the University of Caen, this relief plan is the basis for a

project of a virtual 3D model reconstructed in computer-generated images. The final objective is an interactive model of the entire city of ancient Rome. The visitor to the virtual Rome will be able to wander through a full-scale city and enter most of its public monuments and a few residences. He will be able to access the metadata used for the reconstruction.

Why create a virtual model near the real model? There are two main reasons: one scientific and the other educational. The scientific objective is to: 1. update P. Bigot's model by taking into account the evolution of archaeological and historical knowledge about ancient Rome (www.unicaen.fr/rome). 2. provide a tool for researchers to test the architectural and topographical assumptions and test machines' functionality (www.unicaen.fr/ersam). The educational objective is to provide university and secondary school students, and also the public at large, with a vivid illustration of ancient Rome and an example of the ancient urban reality that is not available through traditional archaeological means.

The first feature of the work was the necessity of choosing a precise date for the reconstruction because in the realm of visual representation, only the synchronic approach has scientific value. The reconstruction of Rome is a photograph of the city at a given point in time: in order to be scientifically credible, the reconstruction must not mix elements from different periods. The team chose the period of Constantine, more specifically the beginning of his reign, between 310 and 320 A.D. The choice was based on several factors. First, it seemed of interest for the visitor to be able to compare P. Bigot's physical model (he also chose this period) and the ruins that can still be seen in Rome (which are generally the most recent antique buildings, i.e. in their state as in the 4th or in the 5th century) with the virtual model. Second, the reign of Constantine is the architectural climax of ancient Rome: the height of its urban development. Third, the later period of Antiquity is obviously the best documented from the archaeological point of view. Finally, we wish to show in the future the different stages in the urbanisation of ancient Rome and, since in archaeology the last layer is the first layer excavated, it seemed normal to proceed in the same order.

Three reasons explain why we do not use a 3D scan of the physical model and why we prefer modelling Rome by hand. At first, the physical model scale is 1/400 and if we had realized a 3D scan, there would have been important approximations on the measurements. The second difficulty is that P. Bigot's model was completed in 1913, with some corrections made between the two world wars. Since the 1950s, there have been new discoveries and some data have been reinterpreted. Since the model in plaster is classified as a Historic Monument, we cannot update it, and thus all the corrections are made on the virtual model. Third, we cannot use the terrain of the physical model, because it is a "plan relief": the hills are voluntarily erased so that all the buildings are visible from the edge of the model. The current terrain of Rome is used even if it has changed drastically in places over the past 2,000 years and it will be corrected afterwards in order to be more similar to the historical terrain. Nevertheless, the physical model is used for the topography: when we digitized it (see fig. 8), we bought a satellite view of modern Rome and we saw that all the

ancient locatable monuments on the satellite view were properly placed on P. Bigot's physical model. In the same perspective, we use the street network of the plaster model because the knowledge on this point has almost not evolved since the work realized by P. Bigot.

Before modelling a building, the team's researchers collect all ancient source materials (textual, iconographical and archaeological data) which make it possible to understand its history and draw plans in 3D. They attempt at first to collect all the Latin and Greek texts on the subject. They take care in finding texts, translating them if need be and extracting the data necessary for the reconstruction. The analysis of the iconographic and archaeological sources comes next. The study of the archaeological reports must be conducted using a rigorous historical method: it is the condition of the 4th century which is reconstructed and this condition must be isolated from all of the available information. When, for a building, all the data concerning the 4th century have been exhausted and when information is still missing, we use what can be extracted from previous and posterior periods or we work by analogy by studying better informed or preserved contemporary buildings which have the same function as the one which is to be reconstructed.

The virtual reconstruction is done only when all the data have been studied and synthesized by the team of researchers but their work does not stop here: a daily collaboration with the modellers is necessary not only to answer questions relative to the creation of the model (measurements, materials used) but also to help them to perceive the context of the monument which is modelled. It is indispensable to understand the history of a building, its function and its impact on society to reconstruct it correctly. The main software used is 3D Studio Max (usa.autodesk.com) for modelling, rendering and passive animation, Poser (www.curiouslabs.com) for modelling sculptures, Photoshop (www.Adobe.com/Photoshop) for creating some textures, and Virtools for the interactive tour (www.virttools.com). Images are calculated by default to represent the situation of June 21st, the summer solstice, at 3 pm.

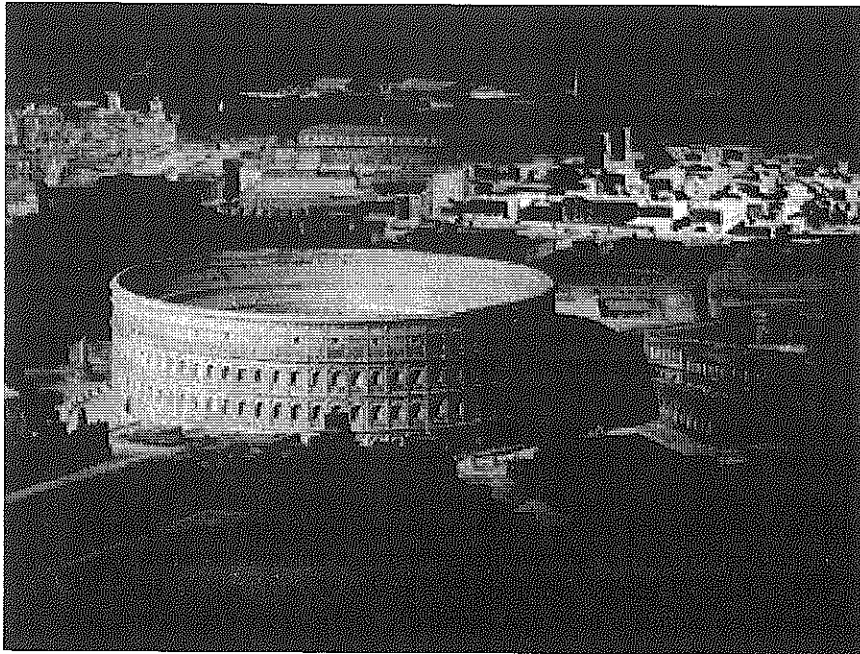


Figure 1: The P. Bigot's plaster model – www.unicaen.fr/rome

2.2 Limitations of Computer Systems in the 1990s

At the beginning of the project in 1994, it was difficult to reconstruct Rome in interactive virtual reality, so we produced pre-calculated videos and we used quick time VR. We spent ten years working with this method, until 2003, and an example of the result is the video calculated to understand how, in the Coliseum, curtains stretched over the amphitheatre (the velum) can cast a shadow to protect spectators from the sun. The reconstruction takes into account archaeological remains and techniques available in the first century A.D. The simulation of the course of the sun (see fig. 2) shows that the system is efficient. Only a part of the audience receives direct solar radiation at the end of the afternoon, when the sun has lost its heat.

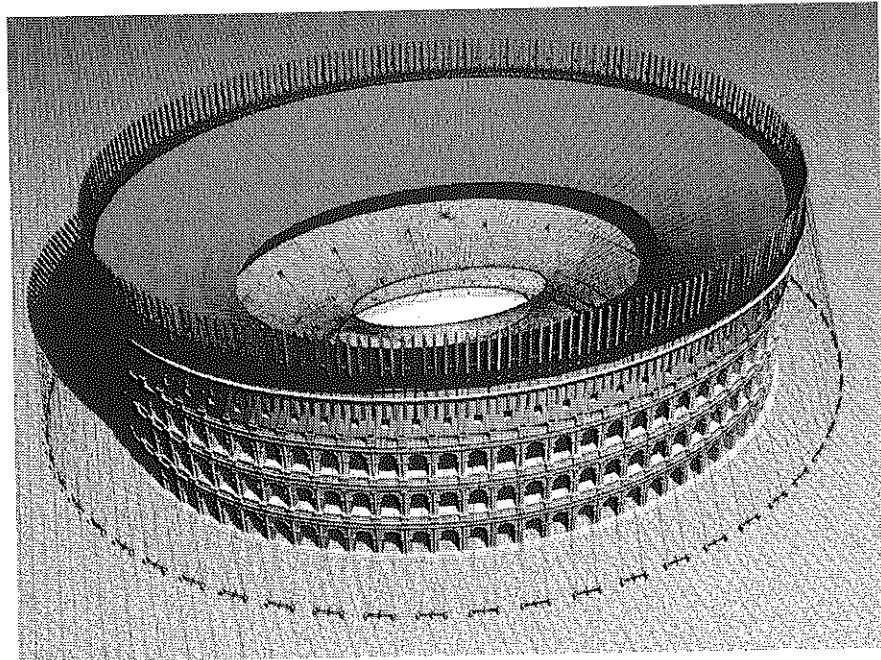


Figure 2: The velum of the Coliseum (see www.unicaen.fr/ersam for a video).

3 Interactive Tour with Dynamic Access to the Metadata

3.1 Definitions

Virtual reconstruction can be further enhanced by *virtual reality*. The advent of what we usually call *virtual reality* took place in the 1980s at the same time as the development of computer graphics. Two fundamental notions are associated with it: immersion and interactivity. Immersion is the operation which consists in going to the other side of the "mirror," seemingly entering into the image. The immersion is physical when an interface (e.g., a 3D head-mounted-display) is used, but it can also be simply mental. Interactivity is the operation which consists in the real-time manipulation or transformation of the image. On this subject, see Burdea & Coiffet, 1993; Quéau, 1993; Cadoz, 1994; Pimentel & Teixeira, 1993. In this project, interaction includes two forms: *exploration*, to explore the environment by the way of navigation, and *manipulation*, to manipulate virtual objects or elements (Parés & Parés, 2001). The exploration is the visit of ancient Rome; the manipulation is the access to the metadata and the testing of machines.

3.2 Why Interactivity?

In 2003, thanks to the new technology and following important progress made in software and computers, the team decided to reconstruct ancient Rome in order

to access and render the model in real time. There are many advantages to making an interactive tour. First, people using the virtual model are not spectators any more, but actors. Whereas with a pre-calculated video, the visitor follows a precise script, the interactive world gives him the freedom to go where he wants, when he wants. The researcher can thus go precisely to the details which he wants to verify. Moreover, moving is calculated as in reality and the exploration of the model can be an experimentation of the time of moving in ancient Rome. Then, the virtual objects can be manipulated in order to access the ancient source materials which allowed the reconstruction. The machines can be manipulated too to see their functioning. E.g. the visitor can lift a load with a crane, point and shoot with a catapult, etc. Finally, the interactive tour is more attractive for the public at large, especially if there is a stereoscopic display.

3.3 The Relevance of the Picture

A relevant virtual picture is the most likely picture given the data we have. It means that the pictures must be complete. We think that reconstructing only what is certain is not a good approach. Romans of the 4th century never saw a half basilica or a temple without its doors. We also think that pictures with different systems to distinguish what is certain from what is not (transparency effects, different colours, models without mappings or with modern mappings) are unsatisfactory. Nevertheless, the models must be based on ancient source material and the visitors to the interactive model must know what is certain and what is less so, with all the nuances between the two possibilities. To solve this problem we work with an interactive model in five dimensions (Golvin). We have the three dimensions of all models that are height, width and depth. However a virtual model is more complete than a physical model since we can walk inside it. The x, y and z coordinates at a given time are not the same as they are at another point in time. Thus time is our fourth dimension. The fifth dimension is the interactive access to ancient sources of data. Behind the virtual model, there is a database with ancient texts, didactic videos, 2D pictures and a bibliography. With this documentation, we provide the visitor with the possibility of consulting the overview of the research data. In reading the interactive documentation, he is able to have a good idea of the degree of reliability of the model. He can see how much data we have, what their nature is and how we have used them. Of course it is an enormous undertaking but this is the best way to show the degree of reliability of the reconstructions. Thus interactivity makes it possible at the same time to show a complete picture and to inform the visitor about authenticity.

3.4 "Marcus"

"Marcus" is the visitor's optional avatar. In the interactive model indeed, the user is no longer in front of a miniature mock-up that he can only gaze at from outside, as in the case with the physical model. Rather, he and the model are on the same scale. He sees Rome as a stereoscopic or monoscopic display according to the system used. He may glance wherever he likes or follow Marcus from a

few meters away. Marcus provides a scale (he is one metre seventy centimetres tall, see figs. 3 and 6). Marcus or the visitor is walking and running at the same speed as a real human. They are subject to the law of gravity. They cannot fly or walk through an obstacle. Thus, the visitor is walking in real time, he can measure the time, what is not possible with other media. It is an important issue for the understanding of daily life in Antiquity. How much time did it take to go from the Campus of Martius to the Coliseum? How long was necessary to reach the highest seat in the theatre of Pompey? The understanding of the time to move is important data for the understanding of events, of the ways of thinking.

3.5 Limitations of the Interactivity

The real-time requirement of virtual reality simulations demands powerful graphics hardware but there are also limitations to the software.

3.5.1 Loading the Model

Virtools is used for the interactive tour. This software can only load one million of polygons at the same time, so in order to maintain real-time interaction with the simulation, the model needs to be optimized during the model management step. It is necessary to establish a scene hierarchy in order to create relationships between 3D entities. Sharing elements can reduce file size and the work load for graphics boards.

3.5.2 Texturing

Texturing an object is the process of adding skin and colour to it. We use our own library of textures, principally created with photos. The max size of texture in a Virtools scene is 1024 x 1024 with 32-bit depth (4 MBytes graphics memory). Our most complete 3D scenes load 1093 textures simultaneously, which represents 1 GByte on the hard disk. This is the current limitation of software and graphics boards.

3.5.3 Light Texture Maps

The next step in creating a realistic-looking 3D scene is to illuminate the scene such that the object becomes visible. When all textures are applied on 3D studio max, the light is calculated by the software for the latitude of Rome at 3 pm on the 21st of June. For the interactive model, light texture maps are pre-calculated, so each texture is loaded with its own shadow in order to maintain a reasonable interactivity and short data extraction time.

4 Interactive Virtual Rome

We now propose a virtual tour in the interactive model of ancient Rome to show an application of this methodology. Virtual tours are available in English on the website www.unicaen.fr/rome, "Virtual reconstruction" / "Already realised" / "Guided tour". As it is not possible to visit all of Rome, we have chosen the

sector of the Campus Martius with a street and the theatre of Pompey. This area lying between the Capitol, the Tiber and the Quirinal was certainly one of the most beautiful monumental schemes of the imperial era.

4.1 The Theatre of Pompey and a Street

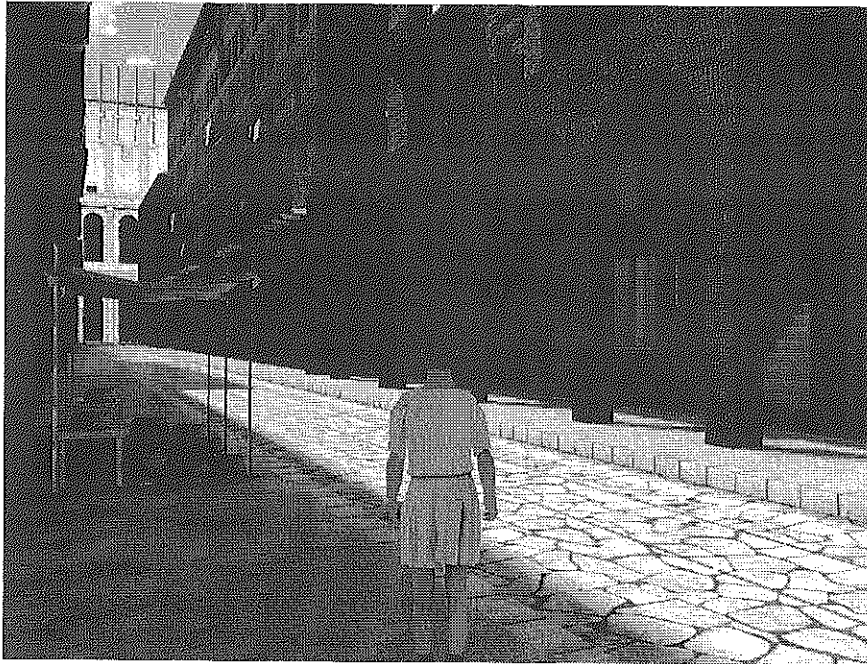


Figure 3: A virtual street with the theatre of Pompey in the background.

The street is important in the ancient urban landscape as the principal location of daily life and is also necessary in the virtual model in order to go from one building to another. In the background (see fig. 3), there is the theatre of Pompey, one of the three permanent theatres in Rome. There was not much space in Rome to house the probably over one million inhabitants. Many people had to live in multi-storey blocks of flats, sometimes there were as many as seven storeys. There were several kinds of *insulae*: some with flats on the ground level, some with *tabernae* or shops on the ground floor but no portico and still others with porticoes. Porticoes are practical for walking down the streets without risking receiving a chamber pot or a flowerpot on the head, as well as in poor weather. We can see *insulae* under construction with their scaffolding. Walking in an alley, it is possible to visit a bakery. Further along the street, there is a “snack-bar”, with meat products hanging up and also food and drink in the snack-bar’s *amphorae*. To enter a private flat, Romans must go upstairs since there is no interior link between shops and flats. It is possible to enter a two-room flat: in the first there are a bed, a table and a *brasero*, reconstructed with models of furniture found in Pompeii and Herculaneum, and in the second a

bookcase and another table with a wax writing tablet. There is one more shop in this virtual street, where it is possible to buy *amphorae* or oil lamps. All the paintings of the model are attested to in Roman cities such as Rome, Pompeii or Ostia for example. Now, we propose visiting one of the main buildings of ancient Rome: the theatre of Pompey which is just at the end of the street.

The Pompeian Campus Martius Complex, built in 55 B.C., boasts Rome's first stone theatre and also includes a temple, a curia, and the first public garden in the city (see fig. 4 to 6). The virtual reconstruction of the entire complex, based on scientific methods, includes simulations of different mechanical systems (effectiveness of the pumps to spray water or manipulate the stage curtain for example). The virtual model makes it possible to visualize the hugeness of the complex and to achieve a better understanding of the mechanical systems used in theatres in antiquity. In the interactive model, we see that the people sitting in the back rows of the theatre could not see the actors very well. This explains why actors wore clothes of special colours according to their roles. It is possible to see the curtain up and we see that its effectiveness is good even if it is only five meters high (see fig. 6). This is the size used in the theatre in Lyon in France. In the *orchestra*, three mechanical systems are installed (see fig. 7). These are pumps to spray saffron-perfumed water in small droplets on the spectators and on the stage. For spectators, it is a kind of air conditioning and probably only the first rows benefited from it. When it was used on the stage, it produced coloured and perfumed haze which can be used during the play. Vitruvius's *De architectura* (Vitruvius, 10, 7, 1-3) helped us to reconstruct the pump (see fig. 7). It is also possible to view an educational video to understand how the mechanical system works. The pump is immersed in water with two men activating it. The virtual environment allows us to propose easily two possibilities for reconstructing this pump: a pump without air in the central reservoir and a pump with air. In both systems, water is sucked up into the central reservoir and a system of valves prevents it from draining back. The problem with the system without air is that between two cycles of the reciprocated motion, the water is not under pressure during a split second, so the water jet is discontinuous. In the other system, there is air in the central reservoir and this air can be compressed when men pump it. Between the two cycles of the reciprocated motion, air is the source of power to push the water through the pipe. With this system, the spray is continuous and it is probably more pleasant than always having interruptions. This same pump was used by the firemen in ancient Rome. It can be turned from right to left and from top to bottom.

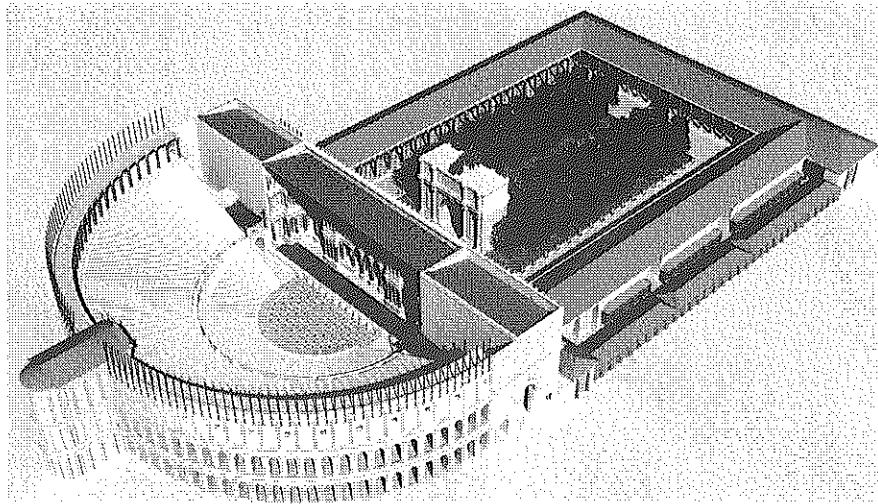


Figure 4: Theatre of Pompey - General view.

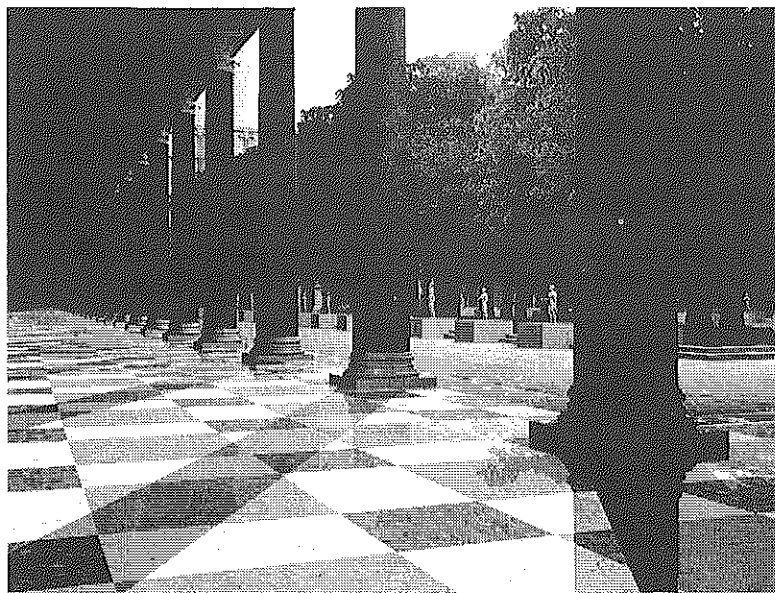


Figure 5: The gardens of the theatre of Pompey.

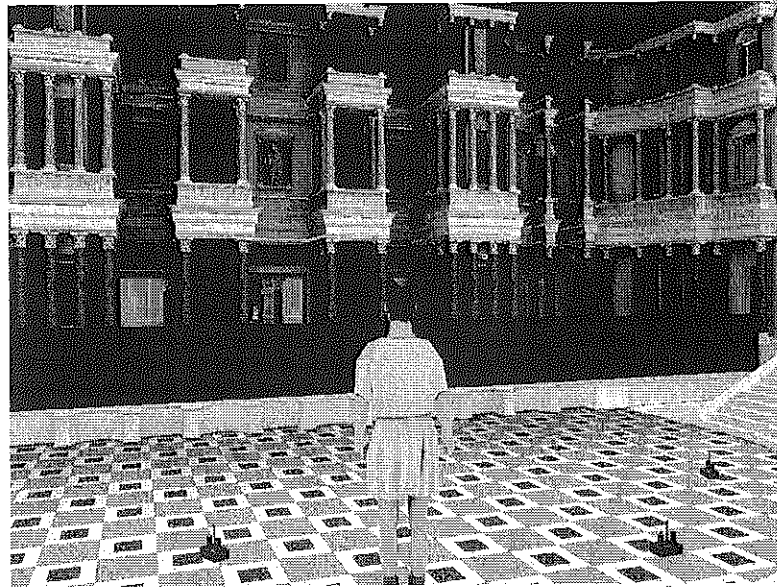


Figure 6: The theatre of Pompeii with the stage curtain up.

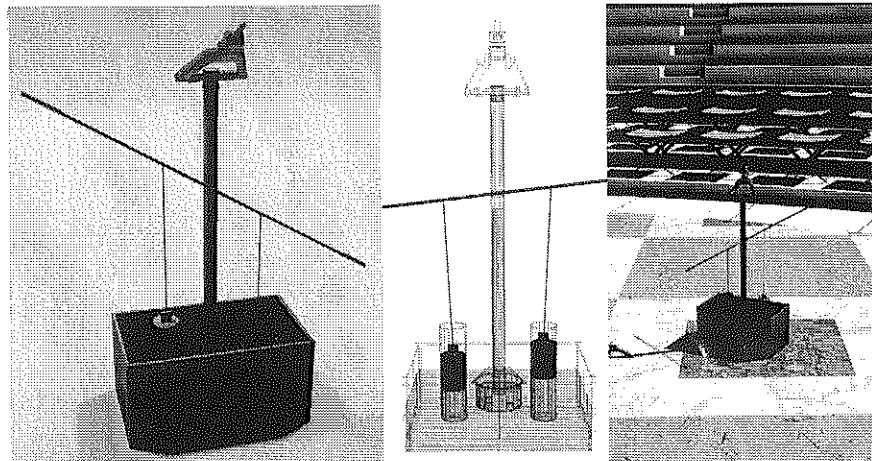


Figure 7: The force Pump.

4.2 Visiting the Entire City

While it is possible to visualize one building or one sector in real time, it is difficult to generate an entire city like Rome with highly detailed 3D building models in interactive virtual reality. With the current limitations of computers and software, we cannot load more than one sector or one building in high quality at a time. That is why new interfaces need to be explored and we program our own basis for data to optimize the model (see fig. 8). Two kinds of buildings

are distinguished: 1. Buildings we can find several times in the city, such as flats, trees and fountains. These objects with redundant geometries are loaded just once, and then are duplicated. There is just one geometry but each copy relies on its own texture in order to have always coherent lighting. 2. Unique buildings are modelled with three different levels of detail: a very schematic model for aerial views of the city, a model with just the exterior of buildings in high quality to visualize a sector and a model with the top level of detail when the user is positioned in front of a building or inside. The level of detail is chosen according to the fraction of the field of view occupied by the buildings. If an aerial point of view is chosen, the entire city is loaded in a low level of detail: architectural detail comes from textures, not from geometry. If a sector is visited, the computer loads the mid level of detail until a given distance and a high level of detail for the buildings is just in front of the user. All the loading is dynamic, so that it is possible to visit the entire city in a high level of detail, even if all of it is never loaded in a high level of detail at the same time.

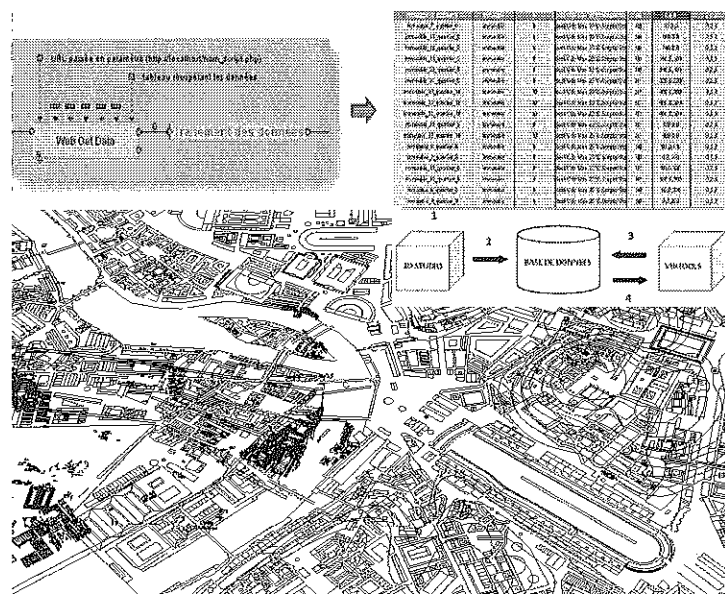


Figure 8: A digitalized view of the plaster model and the basis for data.

5 Conclusion

The work produced by the project can be accessed via scientific papers (e.g., Fleury & Madeleine, 2009), via the website www.unicaen.fr/rome translated into six languages including English and Arabic, and via a stereoscopic display at the University of Caen. Our aim is to give access to the recent research not only to scientists, but again to the public at large. Beyond the creation of pictures, the

interactive tour can be a good approach to understanding our cultural heritage, preserving it and making it accessible in the entire world. The best way to understand a civilization is to travel but this is not always possible. The possibility of consulting an interactive visit on a website is perhaps a solution to make the public at large sensitive to our cultural heritage. The main difficulty is distinguishing scientific productions from imaginary productions because when a picture of the past is produced, it is often considered as a truth, even if it is just a hypothesis. The project SAVE developed by Bernard Frischer in the United States is in our opinion a very good thing. SAVE stands for "Serving and Archiving Virtual Environments" (<http://www3.iath.virginia.edu/save/>) and it will be the world's first on-line, peer-reviewed journal in which scholars can publish 3D digital models of the world's cultural heritage sites and monuments. SAVE offers scholars the opportunity of publishing their models on the Internet with full interactivity so that users can explore them at will. It also offers peer-review and requires that all models be accompanied by metadata, documentation, and a related article or monograph explaining the history of the monument and its state of preservation, as well as an account of the modelling project itself.

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