

# Computer Graphics and Virtual Reality: Two Different Contributions in Archaeological Research

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**Abstract.** This paper attempts to analyse the effectiveness of 3d modelling in archaeological research by exploring the diverse methods available to us for executing reconstructions of archaeological evidence. Starting with the simple subdivisions of computer graphics, as pre-calculated sequences of animation with a photo-realistic rendering, and virtual reality, as interactivity in real-time, it will be possible to highlight the differences between the two methods of display, which, since they are experienced in highly dissimilar ways, will also have a bearing on the goals achieved. The re-examination of the case study of Grave 7 in Romito Cave, and the subsequent improvements to the research, have furnished us with the means to focus our attention on those processes which exploit in a more effective and comprehensive way the uses of 3D for archaeological purposes.

## 1. Introduction

3D reconstructions are generally divided into two main macro-categories: Computer graphics intended as pre-calculated sequences of animation with a photo-realistic rendering, and VR, in its widely accepted form as a real-time rendered animation with different degrees of interaction. (Pringle 2000; Ferko et al 2003). The two genres of 3D reconstructions diverge because of the dissimilar technologies involved during the formulation of the model (Forte M. 2000). The development itself of two distinctive products implies separate objectives and therefore separate target audiences even though they have the same starting point: the re-composition of “spatial variables describing archaeological material, that is any quantitative or qualitative property of archaeological data varying spatially... joining points with lines, fitting surfaces to lines...” (Barceló 2000).

The extant literature and the presentations of various applications frequently ignore this differentiation. End products and goals have been considered from an all-purpose universal viewpoint: the intended user becomes generic when addressing the purposes of research and public consumption. It is our belief that when examining the specificities of the outputs, the contributions inherent in the results and the effectiveness of the methods should be identified and detailed according to the specific aims of the end user rather than described in their broad-spectrum characteristics.

Different outputs aside, the first step in creating 3D models consists of the reconstruction of the archaeological features. This is intended as the result of a process of synthesis and interpretation.

The re-composition of different data and the experimentation with different interpretative options involves mostly the archaeologist-operator during what we will call the manipulation stage: the interaction is between the modeller and the model in the environment in which the reconstruction is created, thus the analytical stage can be performed solely by an expert user. In the case of the creation of a predefined

animation or static image, in other words the form in which we illustrate our interpretation, we arrive at an end product through the modelling process, which corresponds to a secondary step within the sphere of archaeological research. Essentially, since it possesses a remarkable pre-set narrative power, it represents a communication/ dissemination tool targeting a wide range of users who can manage it by means of several browsers. The validity of this tool is associated with the photo-realistic and imposing effect that it produces, and even though this unfortunately is appreciated only as a purely aesthetic experience, it can still be construed as a powerful means to disseminate and promote cultural heritage (Sanders 2000; Wunsch 1999). Furthermore static images of 3d representations are displayed in scientific publications as traditional, but more impressive, exemplificative illustrations. Whereas the actual navigation in real time represents a process in which the interactive exploration of a model, according to the degree of interactivity, leads to an “open system” in terms of personalised visualisation/narration, it is also worth noting that the system runs in a user-friendly environment, thus making it readily exploitable by a large number of users (Ryan 1994; Klastrup. 2003). It is our contention that it ought to be more extensively, professionally, and seriously availed of as an analytical and heuristic tool for researchers rather than merely as a techno-gizmo in its standard “cultural videogame” guise. Its powers of interpretation, explanation, and clarification are frequently misused and overlooked in the field of archaeological research. (Barceló 2001; Forte 2002; Gillings 1997).

By presenting the case study, the 3D reproduction of Grave 7 in Romito Cave, we will attempt to point out step by step how dynamic visualisation offers not only the descriptive power of a real-time exploration but also the use of a tool that allows researchers to effectively and creatively investigate, evaluate, and ultimately share and impart information in a comprehensive interdisciplinary system rather than merely make use of virtual communication in an indiscriminate, random, and uninformed fashion.

Our presentational procedure will be as follows: we will start with a general overview of the archaeological context focussing on the particularities of the studied evidence. Following this, we will describe how we conceived the reproduction based on the use and integration of traditional archaeological documentation and how we decided to improve the resulting 3D model by exporting what we had thus far achieved into a video game engine in order to perform an interactive exploration in a user-friendly environment. We have placed significant emphasis on the results of the taphonomic analysis in conjunction with our pragmatic approach to VR techniques in general so that the conclusions may be assimilated in a logical and natural manner.

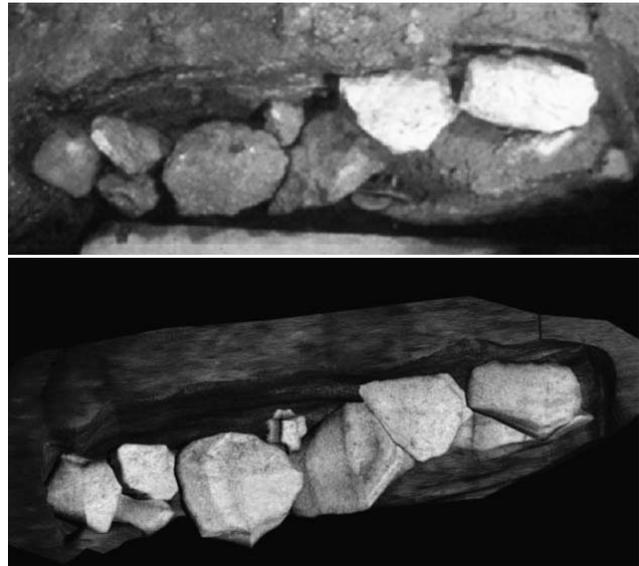
## 2. The Archaeological context: The Romito Cave

The Romito Cave represents one of the most important pre-historic sites of southern Italy. The cave was in use for a long period during the Upper Paleolithic period, culturally indicated as Epigravettian (between 19000 and 11000 BC), the contiguous rock shelter instead revealed a sequence restricted to the last millennia of the Paleolithic (10–11.000 BC). Besides the artifacts and the impressive artistic evidence, the excavations brought to light several single and double inhumations excavated and studied in the early Sixties by Paolo Graziosi, (Fabbri, et al 1989). Since 2000 archaeological investigations have been resumed in the cave, (Prof. Fabio Martini, University of Florence), revealing a new series of single inhumations, (Martini et al 2003).

Grave 7 was discovered in 2001, in layer D5b (12.200 BC), and the inhumation referred to is of a young individual of about 18–20 years old belonging to the Cro-Magnon human group. The singularity of the grave is due to the fact that the body, lying in a very narrow pit, was covered by large stones in an intentionally organized way (three overlapping recognised rows). Although this architecture is not frequent in the Italian Paleolithic period (the only other example comes from Riparo Tagliente in the Veneto region of Italy), the absence of material goods within the grave seems to be a general trend during the Epigravettian culture and is confirmed by the austerity of Grave 7 (Martini et al 2004)

## 3. The Modeling Process

The primary purpose of modelling the prehistoric grave, which was improved in the last year, was to address research questions, with special emphasis on the performance of taphonomic analysis (Viti 2004). By means of taphonomic analysis anthropologists try to determine the post-depositional events (anthropic or natural), which occurred between the deposition of the body and the archaeological discovery and excavation. It is essential for us to understand whether we are dealing with a primary deposition according to the environment (full /empty), and which factors had an impact on the skeleton. The 3D model permits us to explore its state of preservation once the soft components of the interred body



**Fig. 1.** Comparison between the photo of the second row of the stones and an image of nearly the same point of view of the modeled ones.

are deteriorated and to control the displacement of the bones from their original position. From this perspective it became important to execute an accurate model in which all the archaeological and anthropological data were integrated and easily consultable and to pursue a visualization that facilitates an effective three-dimensional exploration

In order to acquire this information the burial place was reconstructed three dimensionally using the data stored in the traditional contour-line map; afterwards the stones were modelled using several cross-sections measured during the excavation. The software used in this first phase was the widespread AutoCad 2002, and Rhinoceros 2.0. The most difficult task was the modelling of the bones since this kind of processing wasn't foreseen during the excavation. To execute the taphonomic analysis, the use of the 2D drawing documentation (scale 1:1) as well as the rich archive of photos was deemed sufficiently accurate. At this step in the process it was essential to possess the competence of an anthropologist in order to identify all the specific characteristics of the bones and their position, most importantly their rotation and their fractures. As a consequence of this anthropological exactitude, the bones have the correct dimensions and the correct positions, since the modelled ones were superimposed on the 2D drawing (the modelling of the bones was carried out in 3DstudioMax 5). What is missing are the details, for example the crests of the bones. It was not possible to recreate part of the skeleton as well since we did not have enough data. Despite these deficiencies, which did not hinder the taphonomic analysis, the resulting model is accurate and reveals its potentiality.

### Further improvements: the interaction with the model.

Considering all the data finally in its broad complexity, we were able to depict the structure in a more straightforward and immediate way, and in a form that is observable from any vantage point, something previously unfeasible also during the excavation stage.



**Figs. 2–3.** Comparison between the photo of the cranium and the modeled one in order to verify the accuracy of the 3D reproduction.

Due to the input of the anthropologist who collaborated on the project (Stefano Ricci, University of Siena), we found it appropriate at this point to further explore and experiment with the re-production in a user-friendly environment. It was also our intention to offer the possibility to any other researcher to iteratively analyse the archaeological evidence from an anthropological point of view, and to increase opportunities to visualise it in a more dynamic way.

Indeed while working with the model in the environment in which it was created, the anthropologist needed to “guide” the operator’s hand to perform with the skill of his expertise so as to render visible those significant areas that, without his supervision, would otherwise have been impossible to perceive.

Since the modelled grave, stones, and bones in their entirety encompassed an enormous number of polygons, which decelerated the regeneration time of the model when navigating interactively (even though we stayed in Shading Mode throughout the process), it was considered essential to decrease the amount of polygons while still maintaining the accuracy of the model and thus to export it to a more manageable environment.

It was necessary for us to fulfil all these requirements. Our solution was to collaborate with experts in video game engines (Insidia s.r.l). We believe that the recent use of video game engines is proving to be a promising development in VA (Anderson 2004; Meister and Boss 2004).

The application was written in C++(Microsoft Visual C++ 6.0), using “Vulcan 3D Engine”<sup>1</sup> technology which is a 3D graphic engine used in the creation of videogames, real-time

computer graphics and virtual reality applications in Microsoft® Windows® (98/ME/2000/XP). Vulcan uses Microsoft® “DirectX® 8.1” libraries that function with any kind of hardware with an accelerated and compatible graphic card, offering high level performance. The benchmarks obviously vary in relation to the power of the graphic card and the configuration of the hardware. However this engine is capable of achieving a high frame rate even on an inexpensive pc such as the one utilised in this project. With the most recent generation of graphic cards it remains feasible to visualise complex scenes (>500,000 polygons) at over 60fps (frames per second). This specific application, named Archeo-VR, is an extremely accessible and user-friendly tool that performs an interactive navigation by means of the most basic of mouse operations: in this case, the view revolves around a point situated along the longitudinal axis of the grave; this point can be translated by moving the mouse and clicking the right button. By clicking the left button, the user activates the zoom mode. These intuitive operations guarantee high freedom of navigation to the user.

By pushing the Esc button, we activate a mode, which triggers the disappearance of the stones one by one, in accordance with the imaging priorities. The stones undergo a fade out effect sharpening our sense of the relative positioning of the stone with the bones.

Since Archeo-VR uses the principal characteristics of the Vulcan engine, the end product is achieved quite swiftly. Moreover the power of the engine enables the user to maintain accuracy despite the reduction of the quantity of polygons. In all: 250,000 vertexes (160,000 for the grave and the skeleton, 90,000 for the stones) and 400,000 polygons (120,000 for the grave and the skeleton and 180,000 for the stones). This kind of performance would not be possible to accomplish in VRLM or with other less powerful engines (Macdonald 2001).

Scrupulous attention was given to the implementation of an accurate high-resolution recreation of the textures, the bump-mapping features, and the light-maps with the overall result of producing a visual quality of superior standard.

At this time the only 3d software exportable to Vulcan is the 3DStudioMax® because only a proprietary copyrighted plugin has been developed, but the future will hold greater opportunities when developments beyond this sole option will permit exportation from different kinds of software.

#### 4. Taphonomic Analyses

Even though the compression of the stones and the partial compression of the hearth (which we decided not to visualize in order to increase readability potential), created a constraint on the skeleton limiting the displacement of the bones, we were still able to view how they were nevertheless affected by them: the ulna and the radial moved away from the right humerus and turned inwards due to the constricted space of the pit. The scapulas, not directly compressed by the stones, collapsed beneath the clavicles; the considerable pressure of stones affected mostly the cranium and the pelvis fracturing these osseous zones. Actually on the upper part of the skeleton



**Fig. 4.** The view of the cranium overlapped by the stone which is visualized while is disappearing with a fade effect in order to better appreciate the relative position.



**Fig. 5.** The top view of the fragmented pelvis.

we can note an intentional organization and interrelation of the covering of the stones. The cranium shows a rotation slightly towards the right with respect to the skeleton axis, and it was blocked by large stones cracking large portions of it along the sutures, and causing its flattening, the frontal section smashing in the two jawbones. The mandible is split in two; the pelvis appears fragmented in the more fragile central part, which has slightly sunk; the two femora show an inward torsion.

The presence of the stone cover produces a mixed environment (full/empty), according to the relative position of the bones. We can also determine and verify the varied impact of the stones on the different bones and then impose this information directly onto the model. Even if this data was previously embedded somewhere in the traditional documentation, we can now explore and analyse all the contributing factors and details in a more manageable and efficient way by confronting and integrating the different sources: in this case the 2D documentation and the photos which were not all-inclusive, explicit, or revealing enough to bring into focus in a meaningful way the specific features of the grave itself.

**Fig. 6.** An example of the dynamic exploration in the inner part of the grave. This view was not viable previously during the excavation phases, the analysis of the 2D documentation or the navigation in 3DstudioMax.



**Fig. 7.** An other example of visualization in the inner part of the grave. From this point of view becomes feasible to analyse the relative position of the bones with the stones.

## 5. Conclusion

We wish to emphasize that the integration of the various sources at our disposal into the 3D representation has been one of the significant tasks of this research. The primary requirement to complete this task must undoubtedly be access to the 3D model and consequently to the archeological evidence in such a way that permits us to work on it. But how to fulfill this basic requirement was not entirely clear until the model was developed. The so-called manipulation stage in this case did not only consist of the modelling itself, which did not require any further interpretative deductions since the grave appears in its integrity, but also of the “visual manipulation” which is to say the performing of a dynamic virtual visualization that goes beyond the scope of the data we had at the outset by furnishing a new and incremented set of data. Thus it became clear that an additional task was engendered: to create a model that should not “... be restricted to “presentation” techniques, but to explanatory tools. VR techniques should be used not only for description, but for

expressing all the explanatory process. An explanation can be presented as a visual model, that is as a virtual dynamic environment, where the user asks questions in the same way a scientist uses a theory to understand the empirical world.” (Fisher et al 2002 :9).

Within the framework of this pragmatic approach, we were logically and inevitably led to fully exploit, from our adopted perspective, all the potentiality of the created model. At this juncture, what we will term the “augmented consciousness stage,” collaboration with the anthropologist became especially crucial. The need to operate without any mediation on the 3D reproduction motivated us to perform the specific taphonomic analysis in a heretofore unforeseen way with respect to the previous aims of the project in which we had considered it sufficient to re-compose the data, analyse the resulting model within the 3D computer Graphic software, and exemplify a set of static significant images, or movie, for presentations and publications. Working in a not intuitive interface and not ductile environment limits the analytical process and restricts the opportunity to iteratively explore the model. Performing the analysis in a user friendly environment by using in this case a video game engine, fulfils the interdisciplinary nature of archaeological disciplines and imparts a more specific connotation to the communicative aspect of VR introducing, with respect to the research field, the concept of sharing data in order to exchange expertise and compare results and analysis, and ultimately deepen our insights and perceptions.

## Notes

- 1 Insidia s.r.l is a videogame development company located in Florence, Italy. Insidia’s main interests are real-time 3d graphics and videogames in particular. Insidia produces in-house all the technologies (3d engine and tools) necessary to develop its titles, and make them available for licensing.

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