Villa Adriana's Serapeum: Optimized 3D Models for Knowledge and Distribution of Archaeological Sites

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Abstract

During the centuries famous architects, archaeologists and painters tried to understand, through surveying and drawing, the original shape of the *Serapeum* of *Villa Adriana*: Many ancient and more recent reconstruction proposals currently seem not to be accurate enough because they were made with empiric or rethoric approach to the ancient architecture. Until now the authors, studying the monumental complex, have represented the complex shape of vault and ruins in a schematic way. Studying and drawings, produced by Canina, Piranesi and French *pensionnaires* (such as Louis-Marie-Henri Sortais), put in evidence a range of different hypotheses. However the complex shape of the damaged masonry walls and of the fallen pieces of the vault were not so easy to represent and survey. Nowadays arranging software from the world of digital survey and video games interactive applications, it is possible to obtain reliable 3D models also suitable for interactive applications for the web.

Advanced texturing systems, based on normal maps, allow to use the huge amount of data, obtained by means of digital survey to improve the quality of 3D models useful in rendering applications. Those models with applied normal maps, encode in low resolution a complex and accurate morphology. It is necessary not only for distribution but also for studies in which accuracy and user-friendliness are important.

Keywords

Virtual museums and public archaeology applications; 3D Data capture and visualization; Virtual reconstructions and visualization: Problems with uncertainty; Qualitative and quantitative analysis in 3D imaging – a matter of scale

Hadrian Emperor's Villa is famous for a number of different reasons: its huge extent, the innovative shape of many of its pavilions (made using ribbed vaults), the complexity of the planimetrical composition and the great number of statues exhibited inside this vast Hellenistic project.

Situated near Rome, it was not just a place for the emperor's "otium", but a never-ending project where Hadrian could experiment his architectural skills by means of developing many typologies.

The treatment of huge amounts of data and the quality of architectural and archaeological representation due to contemporary surveying systems are two of the main themes of the current debate regarding the better ways to share information between different scientific fields.

Starting from the surveying operations by means of *laser scanner* technology, we can obtain point clouds, then the most common procedure is to connect each point with edges that create the boundaries of small 3D faces that represent on the whole the shape of the real object. Using specific software solutions we decimate the number of polygons describing the shape we want to investigate or represent because it is quite difficult (sometimes impossible) to work with such heavy data. By reducing the original number of polygons, we perceive a reduction in the quality of the model: first of all the edges seem to be melted down and all the reliefs (for example the masonry walls, small details and embossings) disappear completely.

The decimation process changes the shape and volume of the surveyed object but, lowering the number of elements describing the object, it is easier to work on these 3D models; we have to remember that every section, 2D drawing, still image represents a different object because the former one has been altered. Fortunately reverse modelling tools quantify the error introduced by means of applying decimation algorithms so we can know the "inaccuracy" of our outputs.

At present many different outputs are possible if we manage and "filter" data from digital surveys:

we can represent archaeological sites through digital animation and rendering (still images) or in a specific interactive solution (real time application for the web).

In many cases the use of complex data, acquired by means of such accurate instruments as “time of flight” laser scanner solution is much too “expensive” in terms of data treatment because the production of multimedia content needs to use low-poly models[1]; so the question is: how to preserve the high resolution of the point cloud models and not to throw away the information about the shape of the acquired objects? During the years we have seen many different solution based on texturing techniques such as bump[2] and colour maps applied on low resolution models, but the process needed to create this kind of images was in many cases empirical or “scientific” but too complex: “difficult to make” a peculiar kind of grey scale image generated by using the “object to camera” distance to encode the shape of the relief in a bitmap.

In the case study of the Serapem of Hadrian’s Villa we used reverse modelling tools to determine the better low-poly shape capable of being computed in the faster way and a technique widespread in the field of video games in order to enhance the quality of the virtual representation by storing the morphological information acquired by full-resolution point clouds in special maps.

The ribbed vault of the Villa Adriana’s Serapeum is one of the few cases in which it is possible to detect the “construction curves” of the shape of this complex pavilion. The quality of conservation of this structure let us use techniques implemented in software solutions from the field of industrial design and reverse engineering. These tools are based on the automatic recognition of entities, such as sharp creases and constant curvature edges that

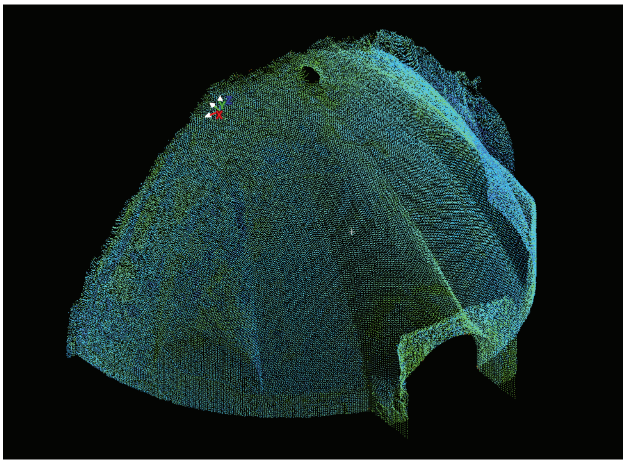


Fig. 2. Point cloud model of the ribbed vault.

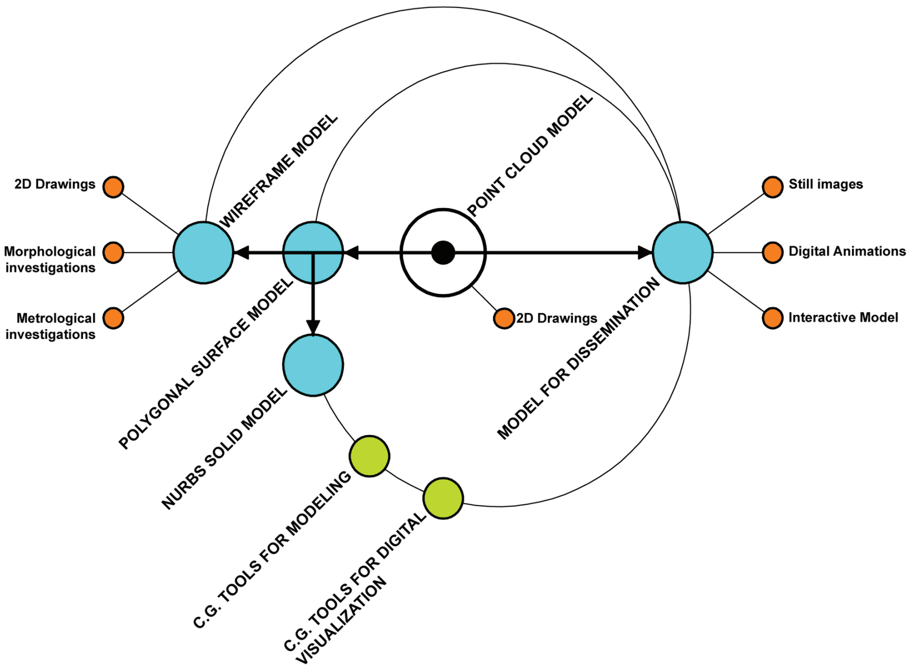


Fig. 1. The scheme of data utilization.

1 Low resolution models made using geometrical decimation tools, modelled using a low number of polygonal elements to describe the real object shape.

2 Gray scale image capable to enhance the detail of a model by means of the deviation of the normal of the polygon computed by render engine while producing still images.

are a prerequisite for building a net of mathematical curves (nurbs curves[3]) that will be converted into mathematical surfaces capable of describing the shape in a less expensive solution for hardware and software capabilities than a high-poly mesh.

Every step of the process described until now introduces a morphological deviation: from the real object to the point clouds and then to the decimated model, etc.; it is important to remember that every passage is linked to a report in which the statistics of the deviation introduced quantifying the final error are stored, with the aim of evaluating the quality of the whole process.

The optimized mathematical representation of the ribbed vault obtained by means of the reverse modelling process is shown in *Fig. 4*, it is possible to see the edges (in orange) and the b-spline patches (in blue) that completely cover the vault.

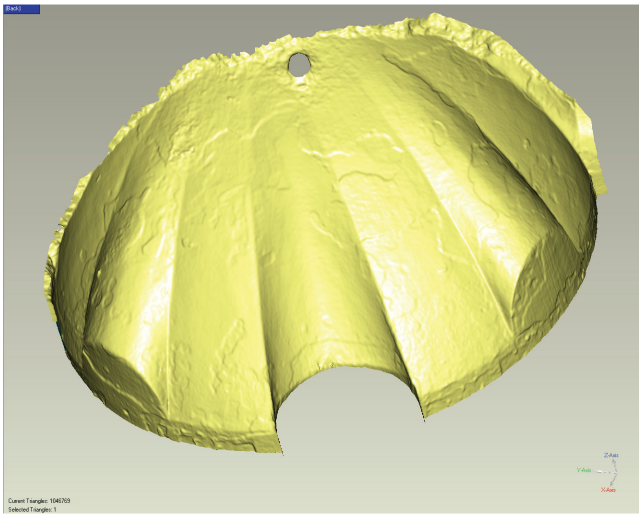


Fig. 3. Polygon mesh obtained by point cloud.

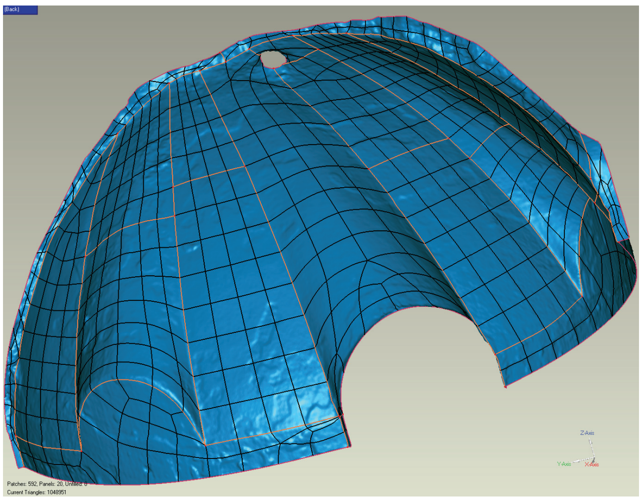


Fig. 4. Mathematical model describing the shape of the vault.

The first consideration that has to be made at this step of the process we are talking about is the inadequate quality of this representation of the description obtained in the rendered image in *Fig. 5*: it is not just a problem of colour but also a lack of morphological information that has been lost in the optimization process: we know the measure of how far from the original point clouds this shape is, but in a still image or an interactive representation it is much more important to perceive the relief of the bricks, damage to the plaster, etc.

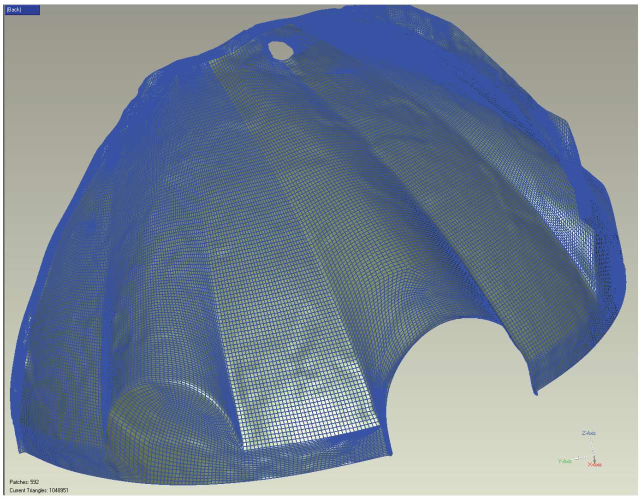


Fig. 5. Optimized mesh automatically obtained by nurbs model.

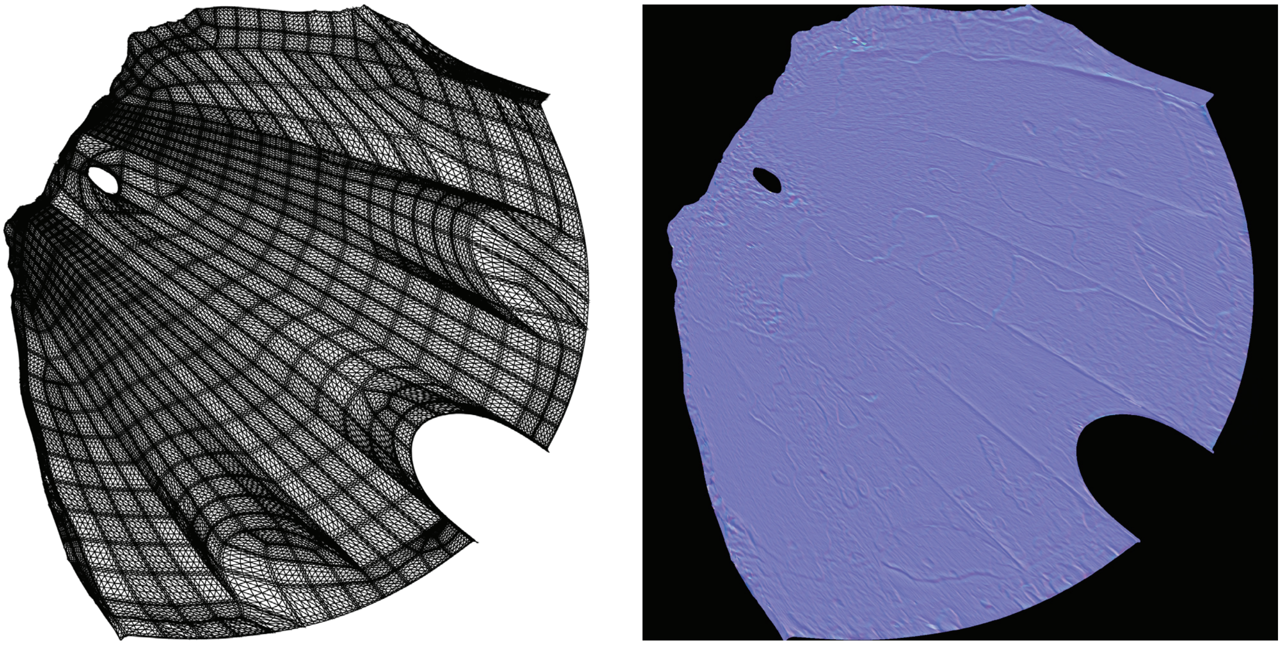
The next step that allows us to obtain a low resolution polygonal model with the perceptive detail of the full resolution one is a procedure called baking.

This term is used in the computer graphics jargon to describe a peculiar kind of rendering obtained using an unwrapped 2D representation of the object as canvas (or more correctly reference system) for the production of this image in which different kind of data are stored (from the diffuse shading to the colour, to complex physical simulation regarding light).

In our case we want to use "baking" to save or encode in a RGB image all the morphological information of the high-poly model in a texture called normal map.

The baking in the case of production of a normal map requires two models: a low-poly one (from

3 Nurbs is the acronym of: Non Uniform Rational B-Spline. This technology is very useful in the industrial design drawing process (Ciammaichella 2002).



Figs. 6–7. UV map used for the normal map baking process.

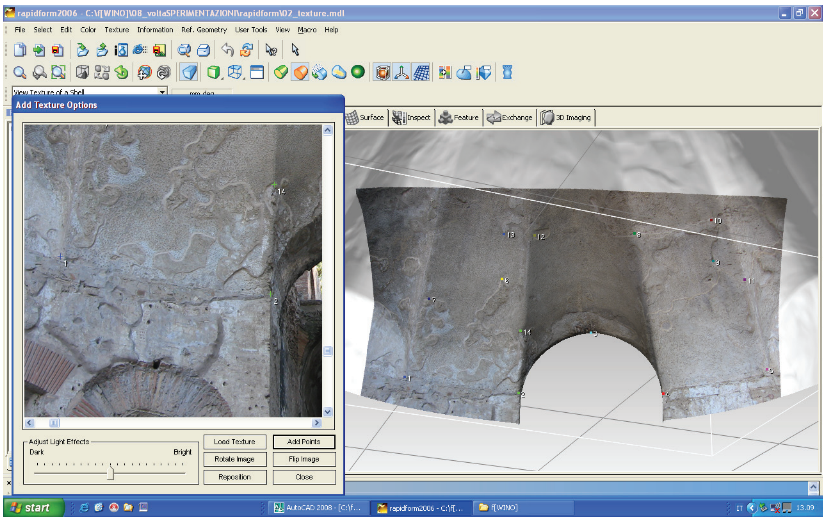


Fig. 8. Omologous point recognition.

the nurbs optimized surface) with a single UV map reference system,[4] and a high-poly one.

The "baking" technique produces a bitmap that, once applied on the low-poly mesh, substitutes each normal of the simplified mesh with an image that encodes the three vector components of each high resolution polygon's normal in the three channels (RGB) of the image.

Using normal maps instead of the previous bump map (one channel bitmap) allow us to obtain a better visualization quality, moreover a normal map is the result of a non-empirical process in which the first step is to define an optimized UV reference system for the low-poly model. Normal maps and colour maps, obtained by means of photogrammetrical survey (*Fig. 8*), can be applied together in order to improve the quality of the 3D model representation.

Once applied, the normal map enhances the details of the low-poly model and makes it possible to perceive the details of the masonry wall (*Fig. 10*).

The combined use of colour and normal maps let us obtain a more accurate representation based on a 3D model and an easier way to manipulate different pieces of the same structure formerly together before the collapse (as in the case of Serapeum). The use of detailed and an easy-to-compute models lets us accurately study and virtually restore the complex morphology of the two pieces of the vault fallen over time.

[4] UV is a texturing reference system, automatically made using unwrapping tools; this powerful texturing solution relates 2D UV coordinates to the 3D space in which the model is placed. This reference system relates the vertices of the model to the pixels of the "baked" image or to those of another image without using standard projection solutions (planar, cylindrical, spherical, etc.).

Many of the pavilions of the archaeological park of Villa Adriana have been surveyed during the last few years using laser scanner technology by the Laboratorio di Rilievo of Dipartimento di Progettazione of the Faculty of Architecture of Florence. The great point clouds database has become the perfect base for many studies and application of new representation technologies.

The process carried out beginning with the *laser scanning* of the Grandi Terme and Grande Vestibolo (2004) and then, the so called Palestra and Cento Camerelle (2005) and moreover recently Serapeum and Piccole Terme (2007) provides new possibilities for engaging methodologies of representation and communication that derive from very distant scientific fields.

Distant worlds that are seemingly incompatible (reverse modelling and entertainment software), if put into relation on the basis of a well-defined objective, can give rise to new research possibilities and development, placing themselves in antithesis in respect to consolidated cliché cooperatives.

Every one knows that the process of the metric datum acquired by means of the current laser scan technologies cannot forgo successive slow treatment, which, as has been noted, compromise the real shape of the objects surveyed in order to let it be publishable in *real time* applications. The procedures that

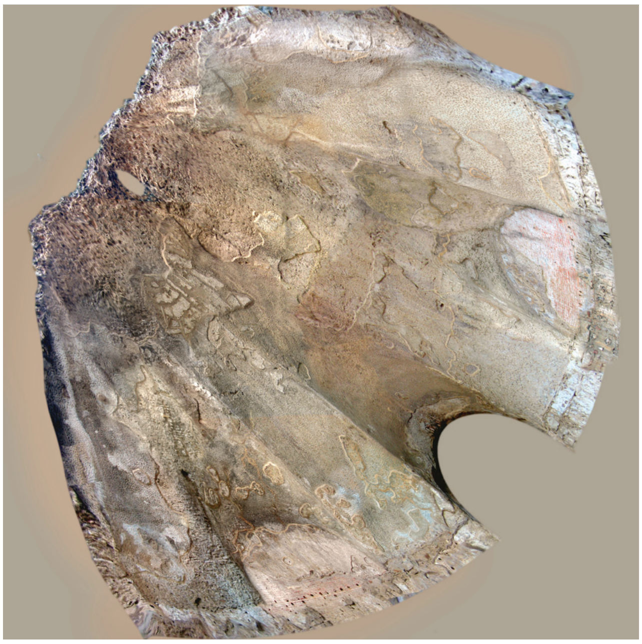
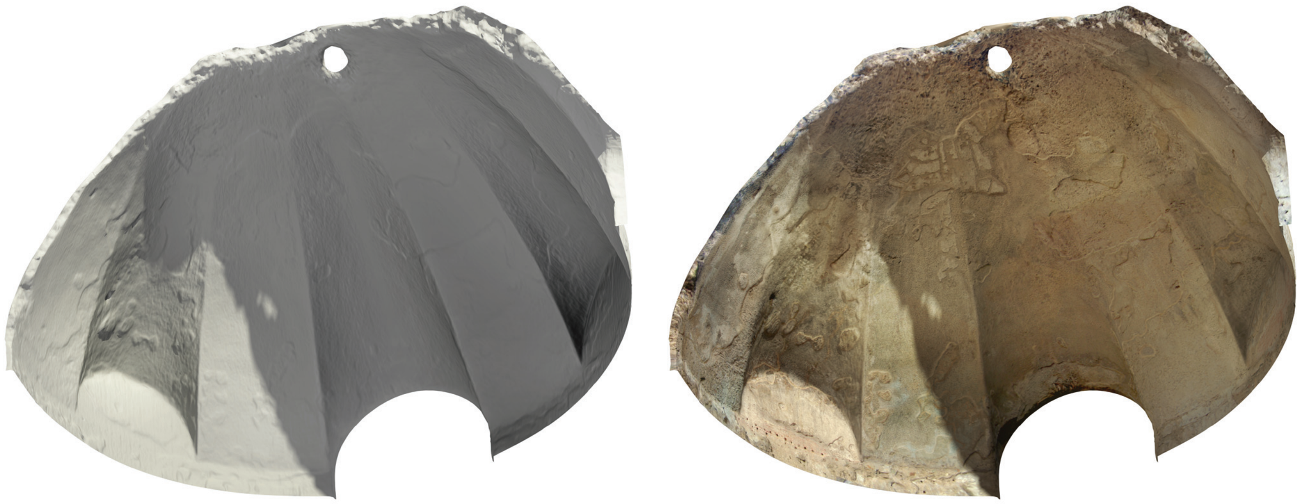


Fig. 9. Color map.



Figs. 10–11. Low-poly mesh with normal map applied ad the one with also color map.

Figs. 12–13. Orthographic view of the low-poly model with both normal and colour map applied.

currently enable such computations to be obtained, cannot forgo the use of the *texture* as integration of the geometric information.

The most significant developments in the field of creation of simplified models, however capable of conveying an elevated quantity of information, are tied to the entertainment industry. Besides, it has been noted that the criteria on which this kind of software is based are very far from the standard system of data-processing. In the application of the ribbed vault of the Serapeum, the combined use of reverse modelling software and normal mapping have, without doubt, provided an alternative answer in respect to the current cliché of restitution in the field of cultural heritage, particularly with regard to the interactive applications and to multimedia elaborations.

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