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NURBS MODELLING FOR THE CONSERVATION OF ANCIENT BUILDINGS

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ABSTRACT

The use of recent software which integrates the use of NURBS surfaces enables us to solve a construction's cognitive track in a completely original way, combining traditional methods of surveying with the possibilities offered by modern IT tools. This study concerns a tomb (IV – III century BC), situated in the ancient centre of Egnazia, and an underground olive-mill (XVI century AD) entirely dug out of rock and with a very irregular volumetric development. The need to obtain a tri-dimensional restitution suggested the adoption of NURBS modelling for the construction of a geometric model which was completely flexible. This was generated by starting from the individuation of a series of curve-sections (*Spline*) carried out *in situ* by means of tri-lateration methods and orthogonal Cartesian co-ordinates. The NURBS model obtained from the union of the single sections. It was perfectly manageable even by calculators with medium-level hardware which were built without resorting to polygonal geometry. Afterwards it was possible to add details of the areas of major interest, and so extrapolate the bi-dimensional processed data necessary for the research in progress.

1. INTRODUCTION

The use of NURBS (Non Uniform Beta-Spline) surfaces for the tri-dimensional modelling has been, until recent times, a precious instrument for research in the biomedical field and for the virtual scenes, especially in the cinema. The evolution of these modelling techniques, their proven reliability and the capacity to check the co-ordinates would suggest to try them out in the fields of conservation and restoration. The three-dimensional reconstruction of a complex structure and its representation by means of NURBS surfaces offers an indispensable base for the understanding and the analysis of the state of conservation of a construction. In fact, this technique is a natural evolution of the traditional bi-dimensional survey.

2. NURBS MODELLING

Tri-dimensional modelling is used to represent objects in 3D space. The most common modeller is the polygonal one. In this type of application, the surfaces are defined like a set of small squares or triangles. The main advantages of polygonal modelling lie in the number of different types of surfaces that can be defined and the ease of converting the CAD/CAM data. The polygons find their ideal field of application in the modelling of objects that do not change shape or that are made up of "hard surfaces" with sharp edges. For the creation of objects with an "organic shape", the number of vertexes necessary for an acceptable definition could be more difficult to manage in comparison with other modelling methods. For this reason, over the last few years, especially in the aerospace and biomedical research fields, the surface modellers that make use of so-called "spline curves" has become more widespread. The most interesting aspect of the use of "splines" lies in the possibility of defining a complex surface by using very few points and in their description by mathematical functions, which are not difficult in calculation terms.

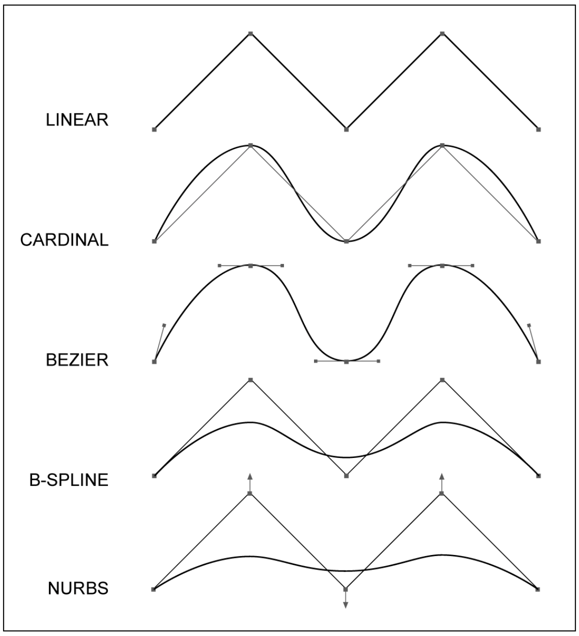

Figure 1

Five types of spline are most common [9], and each of these differs from the other from the point of view of the management of the control points (Figure 1).

- *Linear*: appears as a series of lines that connect the control points.
- *Cardinal*: this curve goes through the control points and allows each point to have a tangency check.
- *Bezier*: this curve is similar to those used in the vector graph programmes; in this case the curve goes through every control point and allows each to have two tangency points.
- *B-Spline*: this type of curve rarely goes through the control points (in this case the points are called "knots").

- *NURBS* work in a similar way to the B-spline, but each knot can have its own weight. A NURBS surface can also be generated by the other four types of curve above described.

The NURBS surfaces and curves do not exist in the field of the traditional design. They were expressly conceived for computer-assisted tri-dimensional modelling. Curves and surfaces represent the external profile or shape of an object in 3D space.

NURBS is the acronym of *Non-Uniform Rational B-Splines*, where:

Non-Uniform indicates that the range of the checks on the vertexes can be very variable. This is of extreme importance in the modelling of irregular surfaces. Rational means that the equation used to represent the curve or the surface is expressed as the ratio between two polynomials, rather than a simple sum of polynomials. The rational equation describes a model or some important curves or surfaces in the best way possible, especially conic sections or spheres.

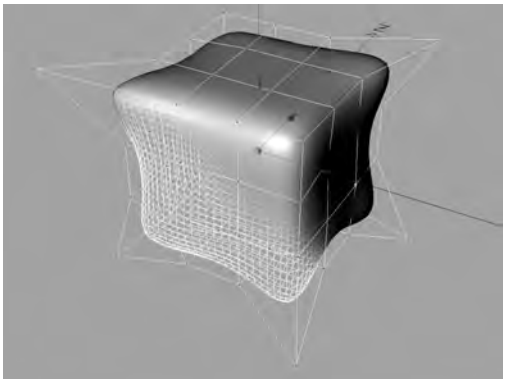

Figure 2

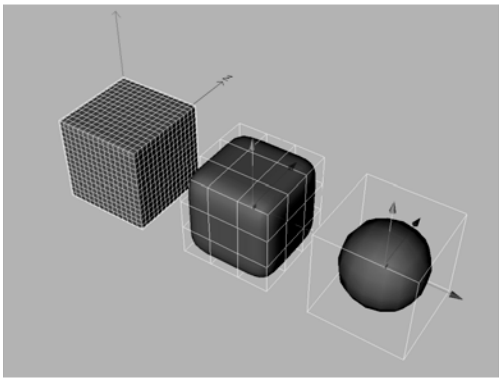

Figure 3

The non-uniform property of NURBS offers an important advantage in the modelling process: since they are generated by mathematical expressions, the objects can be built in a parametric mode, in addition to the normal possibilities of manipulation of 3D geometry.

More specifically, a set of nodes determines the level of influence of each of the control vertexes (CVs) belonging to the curve or the surface. Such nodes are invisible in 3D space and are manageable only in the modelling phase; however, their manipulation influences the appearance of the NURBS object (Figure 2). The software available on the market today implement the NURBS curve in very different ways and offer specific modifying tools depending on the philosophy of the work. For this study we used the *Maxon Cinema 4D v.6* packet, for the modelling and the rendering, which showed remarkable flexibility and reliability even in critical work conditions. The C4D Hyper NURBS, for example, use an algorithm to subdivide and round off an object interactively; this process is defined as *subdivision of surfaces* (Figure 3). With this technology it has been possible to create objects of an "organic shape", like blocks of worked stone, in a

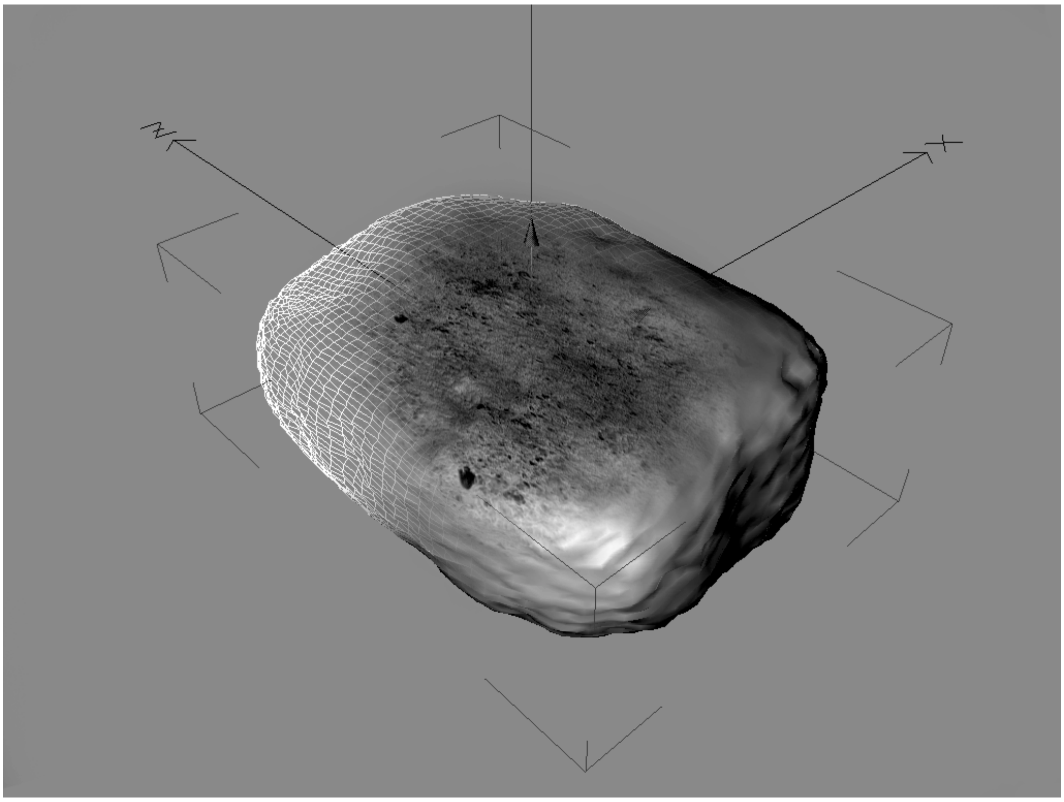

Figure 4

completely original and precise way, while keeping down the dimensions of the file (Figure 4). The instrument used in the most productive manner was the *Loft NURBS* (Figure 5): the splines are used here as profile-sections which define the surface development of an object. Two or more curves are connected in ordered

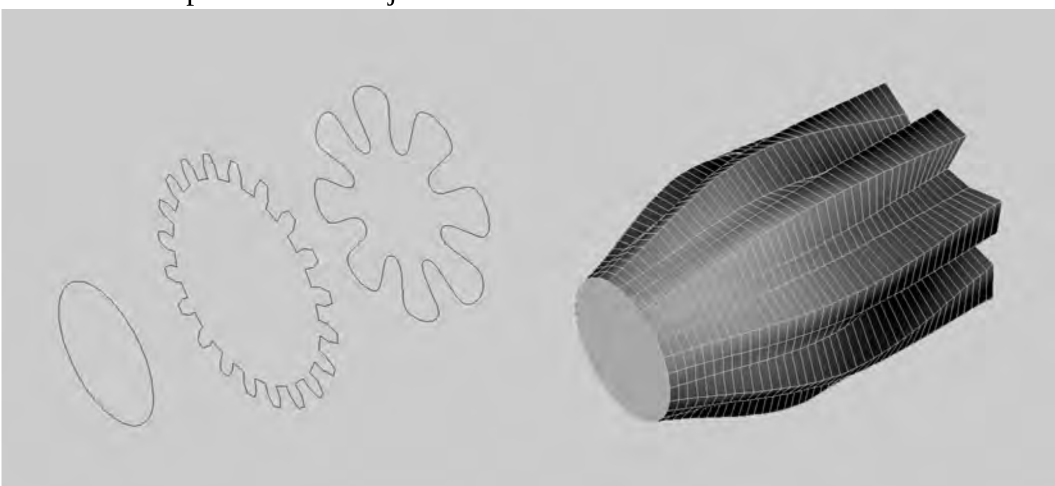

Figure 5

sequence and by means of interpolation the corresponding surface is obtained. Actually, the models drawn up for the reconstruction of the hypogeum olive-mill at Racale (Le) and for the reconstruction of the hypogeum tomb chamber in Egnazia (Br) are *Loft NURBS*. Their important characteristic is that the reliability of the computerized restitution is established by the degree of approximation with which the diverse curve-sections are carried out *in situ* and by the level of subdivision used for the definition of the details. Every model can be described with arbitrary levels of precision, but at any moment it can be enriched with details by simply adding more curves or points on the existing curves. The degree of precision of the representation is, therefore, unlimited. It derives from the specific topic and from the scale factor of the restitution. Then, NURBS surfaces are an ideal instrument for the creation of 3D archives of complex objects and for architectural survey. Their application is even more profitable in the reconstruction of archaeological sites (*Virtual Archaeology*) [4, 8] and ancient monuments, rarely defined by "hard" surfaces. It is, on the other hand, certain that the collection of data acquired about a specific archaeological site is in continuous evolution, in relationship with the new data from the dig. The NURBS surfaces also are useful in the case of rendering or animation phases. The images presented here (Figures 8-10) are a meaningful example of the level of realism achieved, both in terms of modelling, and of visual impact given the advanced capacity of UVW mapping (Figure 6).

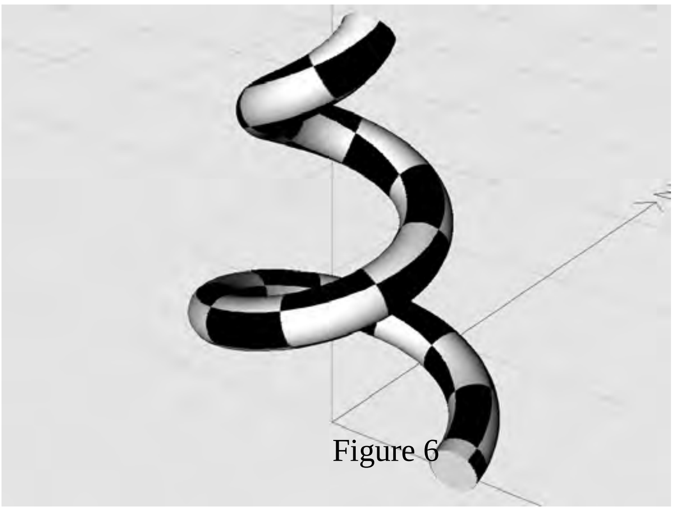
Figure 6

2.1. The Pilaster Tomb

The Pilaster (or Little Gate) Tomb [1, 3] is in Egnazia (Brindisi), a town situated on the Southern Adriatic coast of Apulia and were lived a native population called Messapians by the Greeks.

The chamber tombs date between the second half of the IV century and the II century BC [12]. There are not many of them in the region and they belong to the most important, "aristocratic" families. The tombs are always underground, have an entrance hall and one or more funeral chambers set out in various ways [5, 6]. The Pilaster Tomb belongs to that category of hypogeum tomb which has several funeral chambers. It has a rectangular vestibule (4.80x1.60m) with a NW/SE orientation, on the shorter sides of which two funeral chambers open. Chamber A on the south-east side is irregular in shape, measuring about 5.50x3.90m; it contains a central pilaster and a niche dug out of the central part of the wall opposite the entrance. The

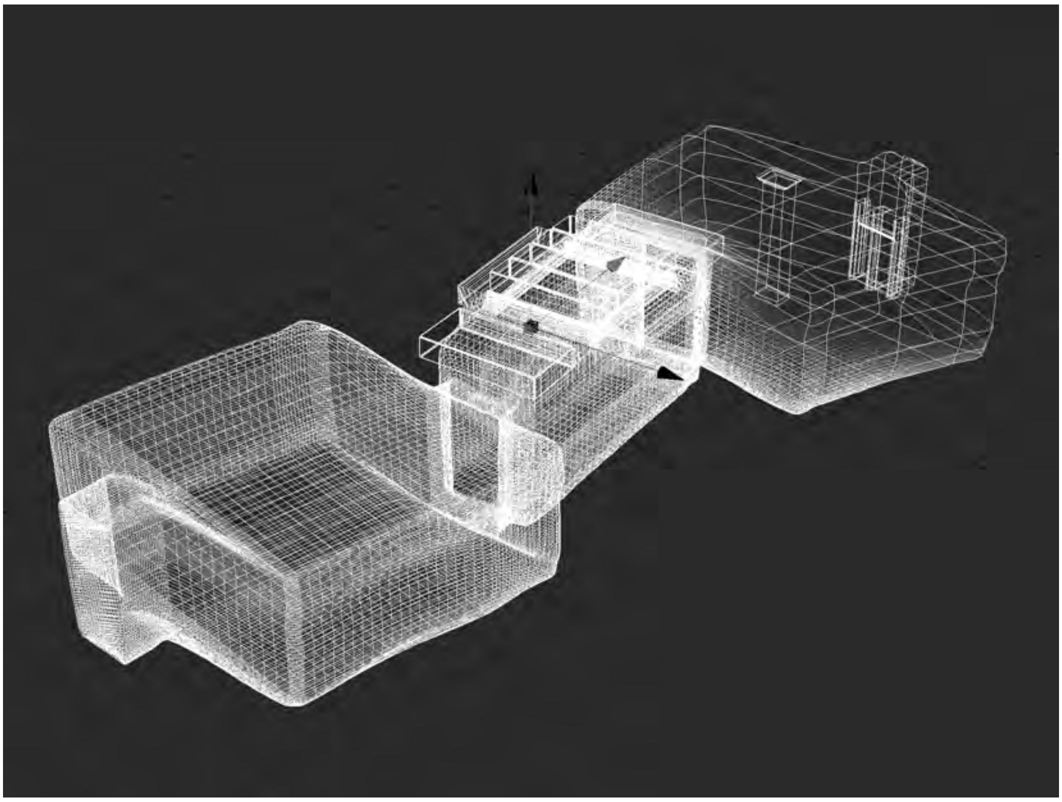

Figure 7

plan of the hypogeum can be compared with two other Messapic tombs: the first lies in Egnazia [3], while the second is in Rudiae [2]. The vestibule has a crowning cornice and is covered in large slabs. All the walls of the vestibule, of chamber A and part of chamber B are plastered and painted. As far as the “construction” of the tomb is concerned, the following phases are showed. First a deep rectangular pit, corresponding to the vestibule, has been dug out of the rock. Then, starting from the walls on the short sides of the pit the excavating was carried out from a “tunnel” to create the two funeral chambers; in this phase the rectangular pit was used to carry off the waste material from the excavations. The crowning cornice and the covering slabs in the vestibule were placed in position once the funeral chambers had been completed.

The survey carried out on the tomb brought to light a series of interesting details from a constructional point of view, which are difficult to spot at first glance. First we see a slight incline, towards the vestibule, of the floors of the two funeral chambers. This is the same gradient as that of the ceilings. The end walls of the two rooms show a certain perpendicularity in the horizontal floors, demonstrating therefore that the apparently “organic”, irregular development is subordinated to the functionality of the whole. This solution was adopted, probably, to guarantee that any water that had infiltrated into the hypogeum would flow towards the entrance, thus keeping the funeral rooms dry.

Figure 8

The 3D study also showed that the residual section of the rock thins out to a thickness of 30 cm in chamber A, so it was therefore necessary to guarantee more structural rigidity; the central pilaster placed in correspondence with this thinning is the architectural solution.

2.2. The Olive Mill in Racale (Lecce)

Underground and semi-interred olive-mills are a particular heritage in Salento (Apulia), connected to the age-old regional production of oil and to the ancient traditions of rural civilisation [10]. These “workplaces” were, from the XVI century on, used for the milling and pressing of olives to obtain the oil. Because of the unhealthy conditions that made these places unfit for working in and of the expanding industrialisation, the olive mills have been gradually neglected and abandoned from the first half of the XX century up to the present day. These places, with their machinery and tools, have become privileged objects of conservation and a living witness to the folk traditions. The Salento mills are prevalently hypogeum, that is, dug out of the calcarenite rock which is “Lecce stone”, “carparo” or tufa. The characteristics of the constructions were studied carefully so as to carry out the various phases of the productive process in the best way and above all, to conserve the oil; in fact, the room temperature had to be warm and constant (18-20°C) which

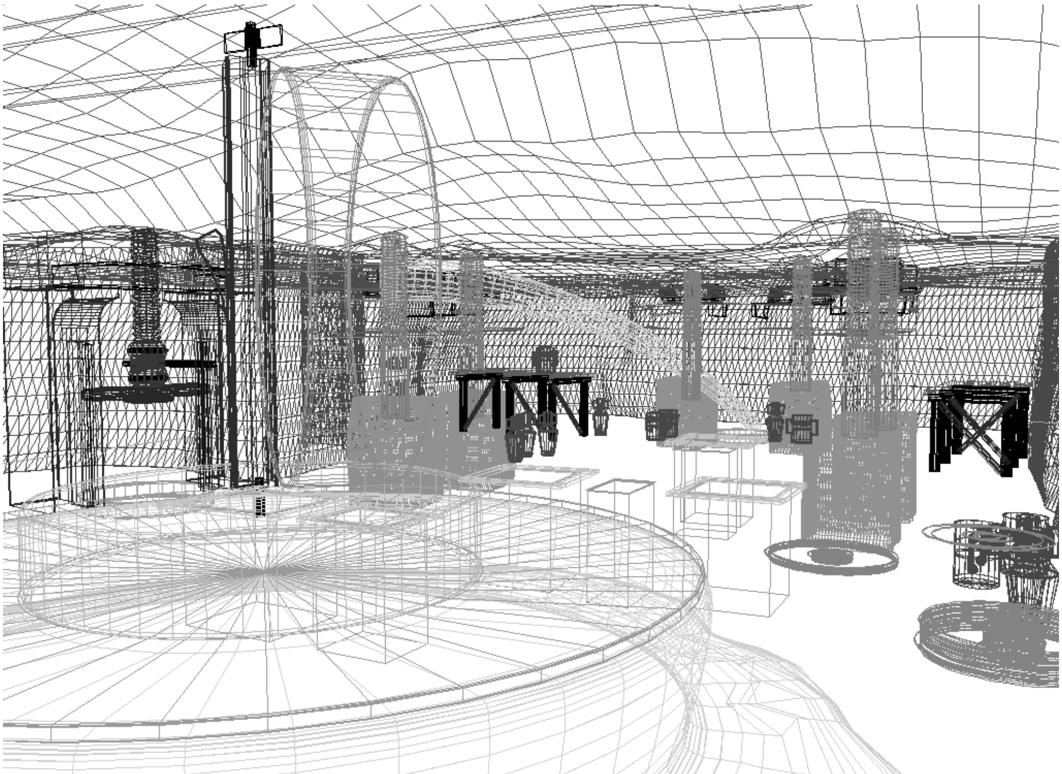

Figure 9

favoured the flow of the oil after the olives had been milled and pressed. The hypogeum can have a floor area from about 3.00 metres to 4.50 metres, thus obtaining an interior height of a minimum of 1.70 metres to about 3.00 metres.

Often the planimeter development seems to be rather articulated and definable as an “organic” structure; so the use of NURBS surfaces for the surveying of the environment has been highly productive both for the comprehension of the tri-dimensional development of the structure and for the geometric/constructive study in plan and section. Even the “machinery” for the treatment of the olives (milling-tanks and millstones) has been carefully reconstructed; this has brought out the planimeter relationships between the parts and their spatial impact inside the working space.

3. CONCLUSIONS

The profile of the curve-sections carried out by traditional methods (direct and instrumental) was seen to be valid for the “macroscopic” restitution of the hypogeums under investigation. On the tri-dimensional models reconstructed by means of NURBS surfaces it was possible to begin studies on the building techniques and the planimeter development of the two hypogeums. However, where the poor state of conservation did not yield a proper reading of the spaces, or the chance to appreciate the details, the work centered on a virtual re-evocation. This represents a way of popularizing, of immediate communicativeness and of particular importance for the transfer of scientific knowledge to the tourist/culture sector [8, 11]. Greater precision in the modelling, where it is necessary, can be obtained by the

Figure 10

use of a three dimensional laser scanner, which enables us to describe the measurements in the form of perfectly manageable “clouds of points”, after an adequate transformation, as NURBS surfaces.

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