# THE IMPORTANCE OF VISUALIZATION. THE USE OF COMBINED 3D SCANNER AND X-RAY ANALYSIS FOR CULTURAL HERITAGE DOCUMENTATION

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ABSTRACT: *In recent times there has been an increasing use of advanced techniques of analysis and documentation in the area of cultural heritage, as happened before with engineering or architecture. Visualization has become a key element in the conservation of cultural heritage that allows the specialist to virtually manipulate the object.*
*The adittion of different layers of information to the virtual models, such as conservation state or stratigraphy, gives the researcher the chance to get a much deeper and complete view of each object.*
*The aim of this paper is to show the advantages of the combined use of two different visualization techniques: X-Ray and 3D Scanner. The results obtained allow us to explore archaeological objects from its core to the surface, avoiding direct contact.*

KEYWORDS: 3D scanner, X-rays, meshlab, documentation, conservation, cultural heritage, archeology

## 1. INTRODUCTION

The process of consolidation of an interesting group of iron objects discovered at the archaeological site of La Bastida de les Alcusses (Moixent, Valencia, Spain) and stored in the Museo de Prehistoria of Valencia (Valencia, Spain) has allowed us to prove a mixed documentation system; our objective was to collect information from the bulk of the objects by means of a non invasive technique, but without losing the reference of the object´s external shape. The merger of the results has provided a layered, useful documentation system, where 3D information related to archaeological aspects or the state of conservation can be added. With the combination of the results from the two techniques, a very useful layered documentation system has been created, where the 3D information related to the archaeological aspects or the state of conservation of the object can be added. Aditionally, the vast choice of applications that allow us to view, edit and share these virtual models facilitate the exploration of these objects, avoiding direct contact, and thus minimizing degradation.

It is essential to bear in mind that the use of advanced visualization technologies should be subjected in all cases to the search of accurate results. The metric accuracy of these models must be tested during the process to ensure that the geometrical information extracted from the model will match the actual values.

In this article we address the specific case of one of these pieces (BASTIDA 162.471). This is an iron horse bit, an object that, once introduced and adjusted between the two jaws of the animal, facilitated their dressage and use.

## 2. EXPERIMENTAL

### 2.1. External data

2.1.1. Instrumentation

Object recording was carried out using a Next Engine 3D scanner. Technical specifications:

- Measurement System: MultiStripe Laser Triangulation (MLT) technology.
- Source: twin arrays of four, Class 1M, 10 mW solid state lasers with custom optics 650 nm l.
- Sensor: twin 3.0 Megapixel CMOS image sensors.
- Photo Surface: optically synchronous 7 color surface capture for precision-locked geometry correlation.
- Photo Lighting: built-in spatially diverse whitelight illuminators with tri-phosphor, wide color gamut.
- AutoDrive: high precision rotary servo positioner, auto-controlled by scanner.
- PartGripper: universal part holder to adjust height, angle, and orientation of capture.
- 5.1" x 3.8" (Macro) and 13.5" x 10.1" (Wide). HD PRO Extended Mode 22.5" x 16.75".
- Resolution: 3D point density on target surface is 400 DPI in Macro Mode and 150 DPI in Wide Mode.
- Texture Density: 400 DPI on target surfaces; 400 DPI in Macro Mode and 150 DPI in Wide Mode.
- Dimensional Accuracy: ±0.005" in Macro Mode and ±0.015" in Wide Mode.

- Acquisition Speed: 50,000 processed points/sec.
- Acquisition software: Scan Studio Pro.
- Apple MacBook with Intel Core 2 Duo Processor. 2 Ghz, 4 GB RAM DDR3, 512 graphics card.

2.1.2. Description of the process

2.1.2.1. Scan parameters definition

Given the object's morphology, a 360-degrees scan has been selected, covering the entire volume of the piece. The whole scanning process has been divided into eight parts and the pointcloud density has been set to 17 k per in2. If this parameter (the number of points in the cloud) is increased, the geometry will be more accurate and the resulting model closer to reality, although the process will require more time and hardware resources.To scan objects in 360º, as in this case, a high precission rotary serbo positioner has been used, connected to the scanner and controlled directly from the PC. The number of scans has been set to eight., so that, at the end of each scan, the wheel has automatically turned one eighth of 360º (45º). It is essential to remember that, between each scan, an overlap area is needed, matching between two adjacent scans. This will later make possible to align the different parts that has been documented.

2.1.2.2. Obtention of a pointcloud

Each individual scan is divided into two phases: acquisition of 2D and 3D information. During the first phase (2D), the scanner emits light over the object and captures digital images, later transformed into textures. During the second phase (3D), the scanner measure the object geometry by means of laser light pulses to obtain 3D coordinates (with information x, y, z). All these coordinates form what we call a pointcloud. At this time we already have an accurate geometric model of the object. As mentioned above, pointcloud density will determine the model accuracy, and a greater number of points will reflect more closely the object geometry.

2.1.2.3. Pointcloud triangulation

This is a fundamental step in creating three-dimensional models. By transforming the point cloud into a triangular mesh, a continuous polygonal surface is created, instead of the previous group of unbound 3D points. And this means that now the model can now be edited in a more logical, fast way.

2.1.2.4. Flat shading

Cover the triangular mesh created with a flat shading is not an essential step in the process of creating the 3D model, but give us invaluable information, from the morphological point of view, on the object you are documenting. Taking advantage of the fact that the textures in this phase are not visible (it is a flat shading), we can focus on the study of purely formal aspects of the object.

2.1.2.5. Texturization

The view of the textured model provides us a great amount of information on issues such as the manufacturing process of the object, coating and decoration techniques and state of conservation. The process of texturing the model is not fully automatic. It offers the possibility to adjust different parameters such as filling holes ( those areas that the software has not been able to fill ). This adjustment is made by stretching the textures detected on the perimeter of the hole and can be very useful in cases where these gaps, either because they are small sized or because they are in an area that is not of interest (in terms of analysis and study) can be covered quickly and easily. In our case we have chosen to scan directly those areas with holes, as in the case of the points of contact between the object and the wheel. The process is the same as described above, and this guarantee greater fidelity of the model obtained with respect to the original object.

Figure.1. Horse bit

Figure.2. Instrumentation

2.1.2.6. Alignment

As already mentioned, the 3D documentation process has been carried out by parts until complete a 360 degrees model, with an area of overlap between each part. Once all the scans have been completed, an alignment process was carried out, using these overlap areas as reference, since they have identical geometries. In this case, the alignment was calculated automatically.

2.1.2.7. Merger

After the alignment process, the areas of overlap show duplicated meshes and textures. This is because, during the alignment process, the information is superposed, but not deleted. That is, at this stage what we have is not a 3D model, but eight overlapping 3D models, with their respective meshes and textures. Therefore it is necessary to merge all the information, in order to obtain a single mesh with one single texture.

2.1.2.8. Features of the model and overall process time

The final model obtained has a total of 294,078 points and 541,498 triangles. The total processing time, including scanning, alignment and fusion was 37 minutes.

2.1.2.9. Export to other formats

The software associated with the 3D scanner that we used allows its export to a wide number of formats:. VRML (1.0 and 2.0), OBJ, STL, PLY XYZ. We have exported the model in VRML (Virtual Reality Modeling Language) 2.0. Once exported, the model can be viewed and edited and specific applications. In turn,some of these same programs can serve as a bridge to export the file to other formats.

**2.2. Internal data**

In this research we go further into the digital readout of the results obtained. That's why we wanted to add internal data to the tridimensional model. Internal structure data and its comprehension from its spatial location allows us to evaluate the state of conservation of its metal core. The X-ray analysis of archaeological materials is an essential part of the processes carried out during the post excavation phase. It has been shown that the most appropriate technique to assess the degree of mineralization of metal artifacts found in an archaeological excavation, as in the case of this research, is the radiographic inspection. The mix between the visible image and the image from a radiographic record can, in metal objects, identify which areas are more fragile.

2.2.1. Instrumentation

The X-Ray analysis has been carried out with a X Transportix model 50, which gives the possibility to work adapting the focus to the volume of the piece. Both kilovoltage range (20-100kV) and electric current (20mA) has been specifically set for this research. An AGFA CR MD4.0 cassette (35x 43 cm) has been used to receive the image. Its universal use makes it compatible with all X-Rays existing equipments. This type of cassette has a phosphor- photostimulable plate that minimizes exposure time, and an integrated memory chip for storing the data acquisited during the identification phase.

2.2.2. Description of the process

For image processing an AGFA CR 30-X digitizer has been used, which can process this record. The CR 30-X unit works with a testing station with the MUSICA software (based on the Multi-scale Image Contrast Amplification algorithm). Thus digital the radiographic image post processing is composed of a wide range of frequencies and gives the possibility of modifying the amplitude of the signal in each of these ranges, process that expands the gray levels management (frequency and density) that are available in the image. This system is the best when a significant gradation of gray levels are needed, and these results are achieved in homogenous radiographic records, typical of researchs conducted on metal objects.For the performance of these radiographic films we have counted on the previous experience in this field, in both analogue and digital radiography, of the Radiologic Inspection Service ( heritage Conservation Institute, Polytechnic University of Valencia). After conducting adjustment tests, the following parameters have been determined for obtaining the radiographic plates: a voltage of 58kV, a current of 20 mA and an exposure time of 3". The object has been disposed on the top of the registration plate and at a perpendicular angle respect to the x-ray source, defining a distance of 100 cm.The image has been processed in the CR 30-X unit and readed at the MUSIC software. Frame adjustments, range of gray compensation and image density has also been processed to export a DICOM image, format easily exportable into any image processing software.

### 2.3. Implementation. Meshlab

Once both external and internal documentation of the object has been carried out, the next goal has been integrate them into a single environment, so the researcher can easily and quickly manipulate both types of information and change from one to another. In this case, Meshlab has been tested to perform this operation. Meshlab is an open source software that lets us work with 3D data from different sources that can be aligned, deformed and edited directly on a 3D environment. A wide variety of filters and tools of measurements and calculations can also be applied.At the same time, Meshlab offers the possibility of working with layers, adding at anytime information in a wide variety of formats, including images (PNG, XPM, JPG). Using the layer management tool, we added the jpg file generated during the x-ray process. Thus, we can select one of the two layers of information, or view both simultaneously.At any time we can save the entire project, which includes the two layers of data, exporting it to the desired format.

## 3. CONCLUSIONS

Obtaining information from archaeological artifacts through advanced documentation methods increases the possibilities for further studies and analysis. However, the ability to visualize, manipulate, edit and share the results is an essential part of the documentation process. The aim of this research is to design a work method that meets the following requirements:

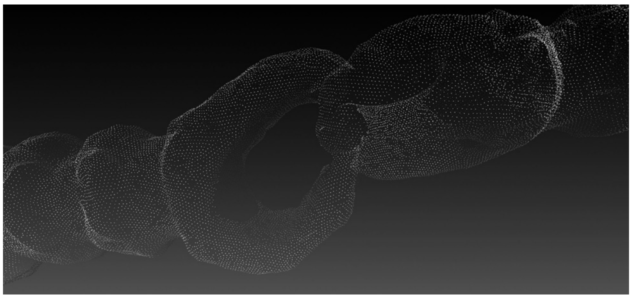

Figure.3. Pointcloud

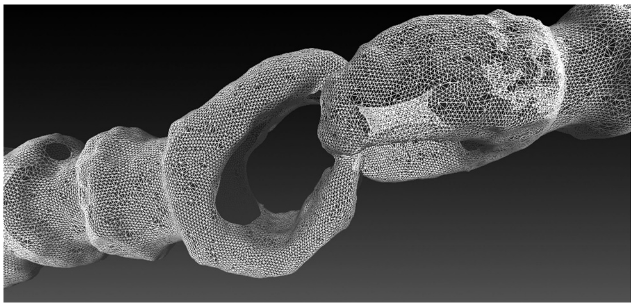

Figure.4. Triangulated mesh

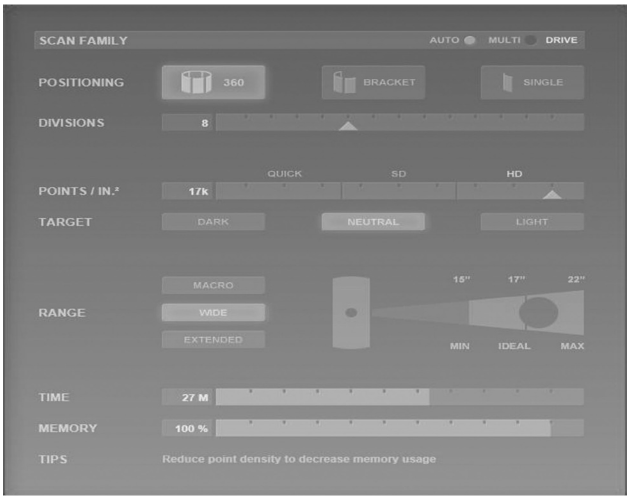


Table 1. Scan parameters

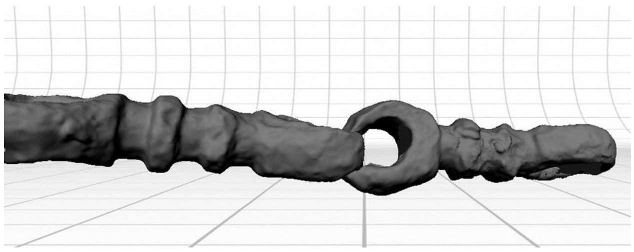

Figure.5. Flat shading

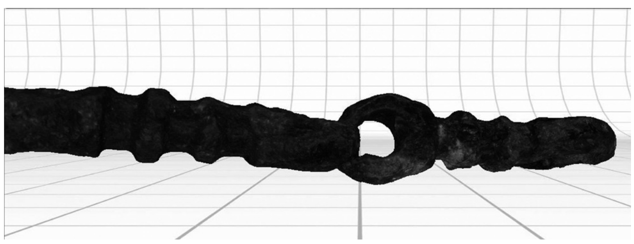

Figure.6. Textured model


Figure 7. Meshlab 1


Figure 8. Meshlab 2

- Minimum contact: must be a non-invasive method with minimal contact with the object.
- Speed: the method must be agile enough to document large volumes of parts in shorts periods of time.
- Ease of use: the use of technological equipment should not be limited to highly specialized personnel.
- Versatility: the results have to be exported into different formats.
- Accuracy: the results should be metrically accurate.

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**BIBLIOGRAPHY**

Arcifa, L., Calí, D., Patané, A., Stanco, F., Tanasi, D., Truppia, L. (2010): 'Lasser Scanning e 3d modelling nell'archaeologia urbana. Lo scavo della Chiesa di Sant'Agata al Carcere a Catania (Italia)', *Virtual Archaeology Review*, **2** 44-48

Bonet, H., Vives-Ferrándiz,J., editores (2011): *La Bastida de les Alcusses*. 1928-2010, Diputación Provincial de Valencia, Valencia

Fell, V., Mould, Q. y White, R. (2006): *Guidelines on the X-radiograpy of Archeological Metalwork*, English heritage, Swindon.

Gibbons, G. (2010): 'Visualization in archaeology: connecting research and practice', *Virtual Archaeology Review*, **2** 11-15.

Jones, D. M. (2007): *Laser Scanning for heritage: "*Advice and guidance for users of laser scanning" in *Archaeology and Architecture*, English heritage, Swindon.

Lang, J. y Middleton, A. (eds) (2005): *Radiography of Cultural Material* (2nd edn, revisada), Ed. Elsevier, Londres.

Madrid, J. A. (2000): *Metodología para la mejora del contraste en el análisis radiográfico aplicado a la conservación y restauración de obras de arte*. Ed. Universidad Politécnica de Valencia. Valencia.

Moser, M., Hye, S., Goldember, G., Hanke, K., Kóvacs, K. (2010): Digital documentation and visualization of archaeological excavations and finds using 3d scanning technology, *Virtual Archaeology Review*, **2** 126-129.

Ristevsky, J. (2006): 'Laser Scanning fo Cultural heritage Application', *Professional Surveyor*, **26** , 3.

*Versión español*

TITULO: ***La importancia de la visualización en la documentación del Patrimonio Cultural. Aplicación conjunta de rayos X y escáner 3D sobre piezas arqueológicas***

RESUMEN: *En los últimos tiempos estamos asistiendo a un uso, cada vez más extendido, de técnicas avanzadas de documentación y análisis del patrimonio cultural. La visualización, como ya ha ocurrido en ingeniería o en arquitectura, se ha convertido en un elemento fundamental en la cadena de trabajo en la conservación de bienes culturales, que nos permite llevar a cabo una exploración virtual sobre el objeto con el que estamos trabajando.*
*Completando, sobre estos modelos virtuales, diferentes capas de información (estado de conservación, estratigrafía, etc.) obtenemos un conocimiento cada vez más completo de la pieza.*
*El objetivo de este trabajo es mostrar el potencial derivado de complementar dos técnicas de visualización: Rayos X y Escáner Láser. Los resultados obtenidos nos permiten explorar el interior y el exterior de piezas arqueológicas, evitando el contacto directo.*

PALABRAS CLAVE: *escáner láser, rayos X, difusión, documentación, conservación, patrimonio cultural, arqueología*