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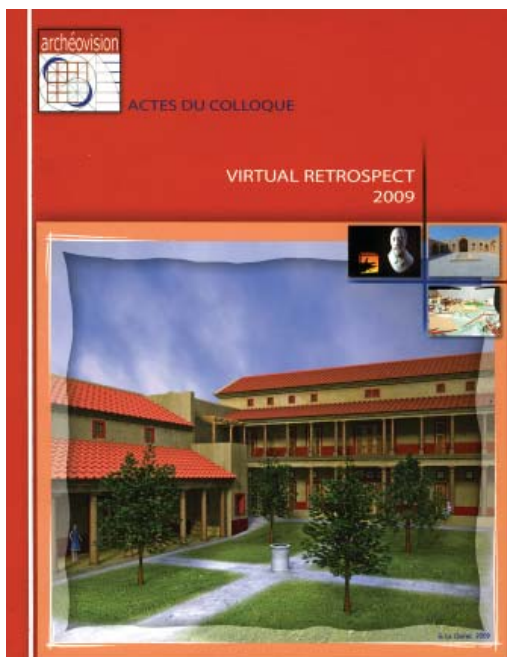
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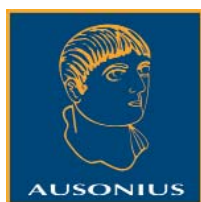
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# Assessment, dissemination and standardization of geometric data recording of Archaeological Heritage obtained from 3D laser scanning

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**Résumé :** Pendant les dernières 10 années l'introduction de la technologie laser scanner 3D et les différentes applications numériques, ont supposé une révolution quant à conceptualisation, à la méthodologie et aux résultats dans le domaine la documentation, la standardisation et l'analyse géométrique du patrimoine culturel.

La documentation du patrimoine archéologique à travers la technologie laser scanner 3D constitue une pièce clé dans la représentation fidèle de tout élément patrimonial, en plus de constituer un véritable dossier documentaire géométrique totalement reproductible diachroniquement, en utilisant également comme outil de contrôle de tout type de modification dans sa structure.

Une des difficultés que représente la technologie laser scanner est le post processus et le manque méthodes ou processus normalisés qui permettent la gestion des données qu'il produit. On a détecté un gap scientifique qu'il puisse décrire comment représenter et conceptualiser les données géométriques. Celui-ci sans doute est un des facteurs que freine une plus grande divulgation de la technologie laser scanner comme instrument scientifique. Pour résoudre ce fait, il existe plusieurs points fondamentaux qui requièrent une attention spéciale entre les différentes méthodes de conceptualisation d'un projet :

- Interactivité et comparaison de processus de registre en rapport avec d'autres disciplines INGÉNIERIE - INDUSTRIE - ENVIRONNEMENT.
- Nouveau langage qui nous permet d'enregistrer la réalité, comme métaphore du terme industriel *as built*.
- Standardisation de processus. Contrôle de qualité et vérification à travers des procédures. Principe d'authenticité.
- Processus de démocratisation des résultats de 3D qui fournissent une diffusion et une divulgation, et de cette façon, une compréhension au grand public.
- Méthodologie multidisciplinaire dans le processus d'étude coordonnée par un technicien spécialiste.
- Adaptation du registre réel à un mécanicien cognitif par une extériorisation virtuelle.

Dans ce travail on développe une méthodologie de registre, à travers des différents types techniques et instrumentation, avec un exemple d'intégration virtuelle d'art rupestre dans la *Comarca*

*del Matarraña* (Teruel, Aragon), avec d'autres fragments extraits de son placement original qui se trouvent dans le Musée Archéologique de la Catalogne (Barcelone).

La méthodologie permet la documentation d'abris rupestres dans son contexte, et de les intégrer de la même manière avec d'autres éléments extraits de son environnement naturel. Ce processus est développé à travers une technologie laser scanner combinée et associée avec d'autres techniques (topographie, photogrammétrie et géodésie), au bénéfice d'une analyse scientifique normalisée qui permet de reconstruire virtuellement toutes ses parties, en plus d'effectuer un contrôle périodique de sa structure qui prévoit tout type de pathologie morphologique. Une autre question fondamentale traite de la création d'une base de données normalisée à travers un environnement web 3D – formats type html, pdf 3D, vrml –, dirigé vers une plus grande divulgation du site archéologique de manière graphique et surtout géométrique, qui permet d'une façon rapide et précise la visualisation de tout élément ou d'une partie de sa structure. Pour cela on prétend un développement combiné, qui sert pour une plus grande valorisation et une divulgation de l'information obtenue, et qui contribue en plus à une étude scientifique interdisciplinaire qui résout les différents gaps méthodologiques et de conceptualisation.

**Mots-clés :** laser scanner 3D, art rupestre, méthodologie, processus et standards, documentation géométrique du Patrimoine Archéologique

**Abstract :** The last ten years have witnessed the introduction of 3D laser scanning technology, along with its derived digital applications, revolutionizing the conceptualization, methodology, and results obtained from the process of data recording, standardization and geometric analysis of cultural heritage.

For archaeological heritage, 3D laser scanning data recording is key for the life-like representation and characterization of any site feature. Furthermore, it generates a geometric data archive, which is diachronically reproducible, enabling its use as a control instrument for any alteration in the structure.

However, the lack of standards or normalized procedures, both in development and management of the three-dimensional models, has resulted in the under-use of all its resources.

Therefore, the aim of this paper is to create a series of standardized procedures that may establish a logical procedure, valid for both scientific purposes and for inter-disciplinary dissemination.

**Keywords :** 3D laser scanner, rock art, methodology, standards and procedures, geometric recording of Archaeological Heritage

## INTRODUCTION

3D laser scanning technology is focused mainly on recording and analyzing any object or structure in multiple fields or disciplines. The data may be applied later to the recording, conservation or restoration of cultural heritage (archaeology, architecture, palaeontology), or connected with another sectors related with reverse engineering and creation of 'as built' planimetries, like industry and civil works<sup>1</sup>. Its inter-disciplinarity allows for the use of other pioneering applications, related to environmental studies, with the aim of predicting and controlling soil erosion, GIS recording of the landscape, biomass studies, analysis of poorly accessible areas, and hydraulic studies<sup>2</sup>.

With the information generated by this tool, an exact and precise 3D model is generated, which is used later in many analyses, in order to optimize the knowledge and recording of the monument. Furthermore, this technique allows to tackle new methodological approaches, thanks to the creation of 3D data bases.

The topic addressed in this paper is related with the post-processing of the data generated by the scanner. While using this tool, we have identified a scientific vacuum in the way to proceed to the representation and conceptualization of geometric data. We noticed there was a lack in standardized methods or procedures that would allow for a satisfactory dissemination of the laser scanner as a scientific instrument<sup>3</sup>. In order to solve this problem, there are several fundamental points that require special attention.

## METHODOLOGY: EXAMPLES OF ROCK ART RECORDING

The geometric data recording of rock art in galleries or shelters is greatly complex and involves its own specific casuistry. More concretely, the main obstacle is the physical medium of the art, narrow galleries or rock shelters in rugged areas, not easily accessible. In addition to the logistical difficulties, the recording itself poses problems, because of the natural irregularities in the painted surface and the particular chromatic characteristics of the paintings. Likewise, it is essential to represent and relate the spatial logic with a contextualization and recording of the immediate surroundings.

1. Angás & Leorza 2009, 40.

2. Playan *et al.* 2009.

3. Forte 2006, 38.

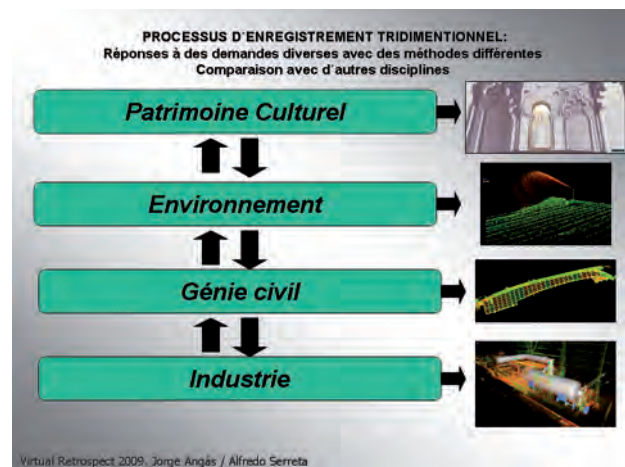


Fig. 1. Interaction with other recording processes used in other disciplines.

The whole process of three-dimensional data compilation is centred, firstly, in achieving a life-like record, incorporating and reproducing every detail in the creation of a database. Once this is achieved, new scientific criteria may be introduced in its study and analysis. Its use enables us to obtain millimetric data that allows for the study of engravings, inscriptions or any kind of trace, but it also morphologically places the studied object in its macrospatial environment. The record may be used as a new scientific medium, both in prevention, protection and conservation, and in its later cultural dissemination.

All these factors, jointly with the work of an inter-disciplinary team, allow for the creation of a spatial logic, enclosed in a three-dimensional model, from which series of data originate and branch out, facilitating its scientific use by other disciplines.

For our case of study, we have been able to create a procedure for the recording process. Rock art in County Matarraña (Teruel, Aragón) has been virtually integrated with fragments previously extracted from their original location, and which are now kept in the Archaeology Museum of Catalonia (Barcelona). This paper develops a recording methodology, using different techniques and instrumentation.

This methodology allows the recording of rock shelters in their context and their integration with other elements extracted from their natural surroundings. The procedure was developed with laser scanner technology, combined and associated with other techniques – topography, photogrammetry and geodesy. The aim is always to achieve a standardized scientific analysis, resulting in the virtual reconstruction of all the parts, as well as enabling a periodic control of the structure to avoid any kind of morphologic pathology. The association of laser scanner technology with

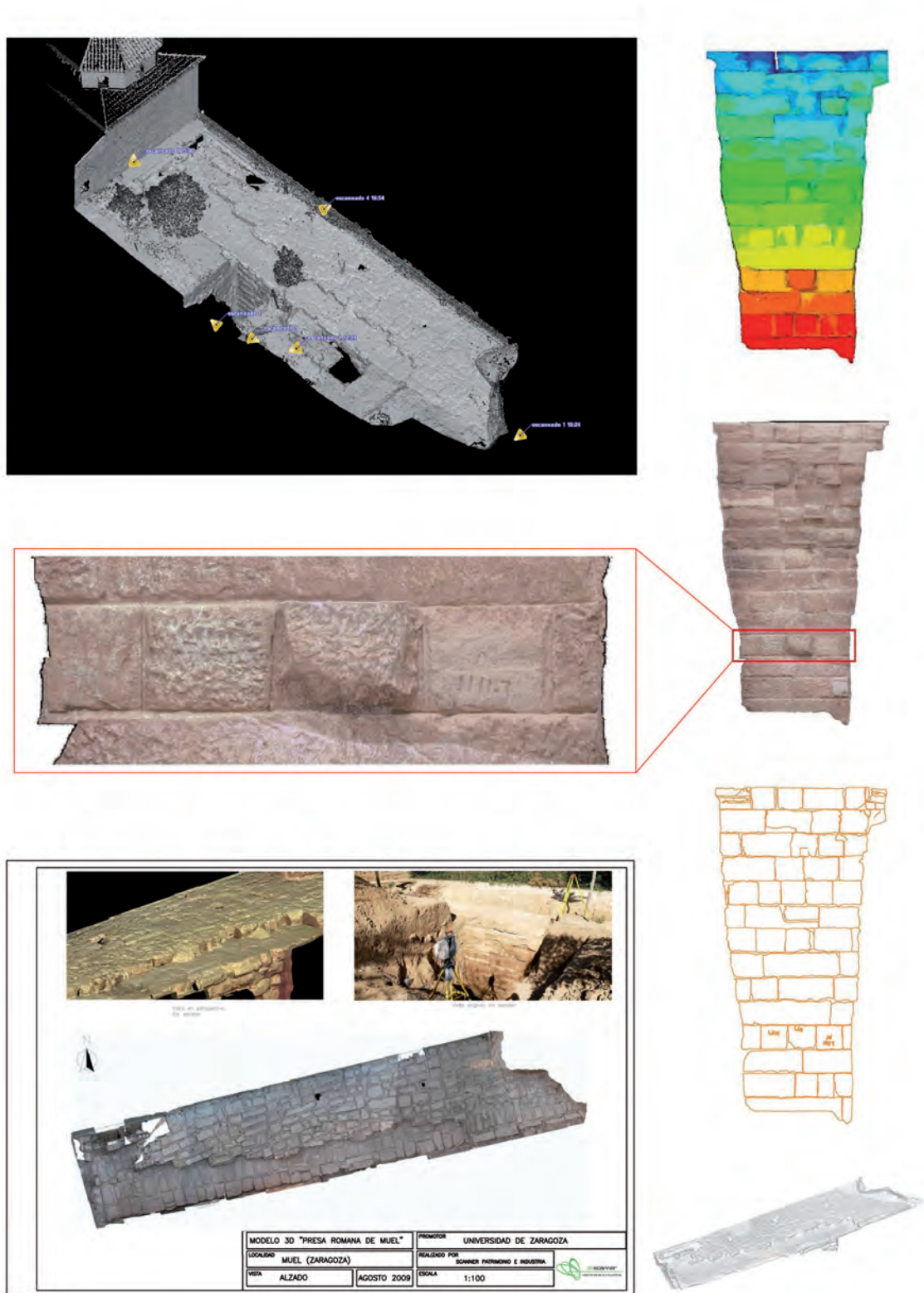


Fig. 2. Composition of different 3D models in a standardized format U3D, from topographic plans and elevation map obtained from the three-dimensional model. This application allows the interpretation of the current metric slope by means of a chromatic scale (Roman Dam of Muel. Zaragoza, Spain).



Fig. 3. Register by means of phase-shift laser scanning technology and photogrammetry of the Levantine rock art site called "Plano del Pulido" (Caspe, Zaragoza). On the right side there are different user-level software viewers from the model 3D.



Fig. 4. Process of geometric data recording by means of triangulation-based laser scanning system. These rock art fragments were extracted from its natural site. Currently they are in the Archaeological Museum of Catalonia.

other classical topographical techniques is essential, both for data recording and structural control and for the diachronic expansion of the area under study. In order to make this work, a connection was established with the generated data through a local coordinate system, geodesically referenced to the official European system ETRS89. Later, a series of topographical bases were recorded throughout the site as points of structural control.

For the last stage, we are creating a standardized database through a 3D web environment – enriched with common formats of the type html, U3D, vrmf. The choice of format is directed towards a greater dissemination of the archaeological site, in a graphic, but more important, in a geometric way,

permitting a quicker and more precise viewing of any element or part of its structure. Information is organized by using web servers as data managers.

The application of 3D laser scanner methodology is a new, avant-garde technology, able to solve the problems and limitations posed by other recording methods.

Various methods are combined in the recording process: different types of 3D laser scanning-phase-shift, triangulation, time-of-flight-, georeferencing with a GPS RTK, and finally the fitting and linking of reference points with classical topographical methods. The role of photogrammetry is key, since many times it is necessary to use these cameras to improve or directly substitute the scanned image. This happens due to

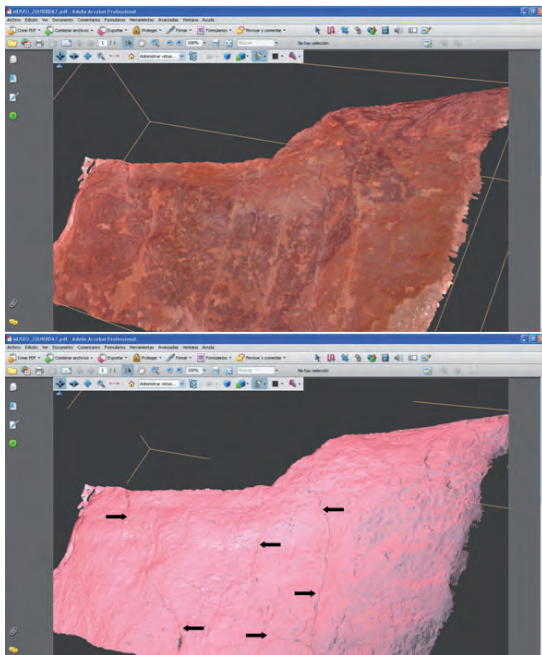


Fig. 5. Obtained results of a panel who represents the figure of a red deer (Levantine rock art) in a standardized format U3D, it comes from the called site "Roca dels Moros" (Cretas, Teruel). The application of different filters allows to appreciate the different fissures at the extracted panel.

the lack of resolution in the cameras of the scanners, but also because shooting angle is lost from the station. Optimal rendering of the image is achieved for each of the millions of points recorded by the scanner. To produce a render and improve the RGB, it is necessary to obtain points identified in the photogram related in x,y,z coordinates with the 3D model, and then adjust radiometrically. The application of this technology produces orthophotos, interactive visualizers, and integrates the 3D model in web servers.

The second problem appears during the standardization of the post-process, and is closely related to the difficulties that arise when managing three-dimensional data. The use of this tool in the last decade has caused the appearance of other problems related to three-dimensional information management, which are summarized below:

- Computer management of the formats. It is necessary to use generic storage formats, such as ASCII or similar, which are compatible in the long term with any software.
- Graphic representation of the three-dimensional data in two-dimensional media. This methodological inconsistency still has a long way to go in achieving a conceptual change from the inherited methodological culture.

#### STANDARDIZATION OF PROCEDURES FOR THE DEMOCRATIZATION OF THE THREE-DIMENSIONAL CONCEPT

In order to standardize the management and dissemination difficulties posed by the data generated by the scanner, it is

necessary to invest in the creation of applications that are compatible with user-level software. This would simplify the three-dimensional data, as well as achieve both scientific and divulgation purposes. The search for a method that will manage the three-dimensional record of Cultural Heritage in a straightforward way is ongoing.

Interaction with other recording processes used in other disciplines, such as engineering, industry or environmental sciences, has been scant. Related with Engineering, for instance, we can use the industrial term as *built* as a metaphoric concept for the recording of reality. In these fields there is a higher standardization of the procedures, which leads to the control and assessment of the method<sup>4</sup>. Consequently, the procedure is used as a principle of authentication for the recording process. Our research ultimately aims at carrying out a "democratizing" process of the three-dimensional data. In the same way that a scientific *corpus* is generated with the obtained data, it is necessary to spread this data to the whole of society. With this purpose in mind, we have created several documents in formats that are easy to understand and easy to manage, making a greater dissemination of the monument, and providing a better understanding of the archaeological site for society.

Our rock art case study has been managed and supervised by archaeological technicians, supported throughout by a multidisciplinary team made up of geologists, surveyors, archaeologists, and engineers.

#### CONCLUSIONS

Technological innovation has developed much faster than its own understanding and methodological management, and lacks a *corpus* of procedures for the correct planning of the process. This standardization, mentioned in the previous section, should include the following premises:

- ACCESSIBILITY. Integration in databases, which are compatible with web servers and may be updated at different levels of access and editing.
- COMPREHENSION. Use of compatible formats, common and exchangeable with user-level software: \*.html, \*.pdf (3D), \*.U3D, \*.vrml, \*.skp, \*.stl, \*.xml.
- GEOMETRIC UTILITY. Obtain measurements and location of absolute coordinates<sup>5</sup>.

The whole process has been developed with the use of 3D laser scanning technology, combined and associated with other technologies (survey, photogrammetry and geodesy). Interest in a standardized scientific analysis lies in the potential of virtually reconstructing and recovering all parts of the studied object, in its different uses and time periods,

4. Roecker 2008, 345.

5. Valle 2007, 162-164.



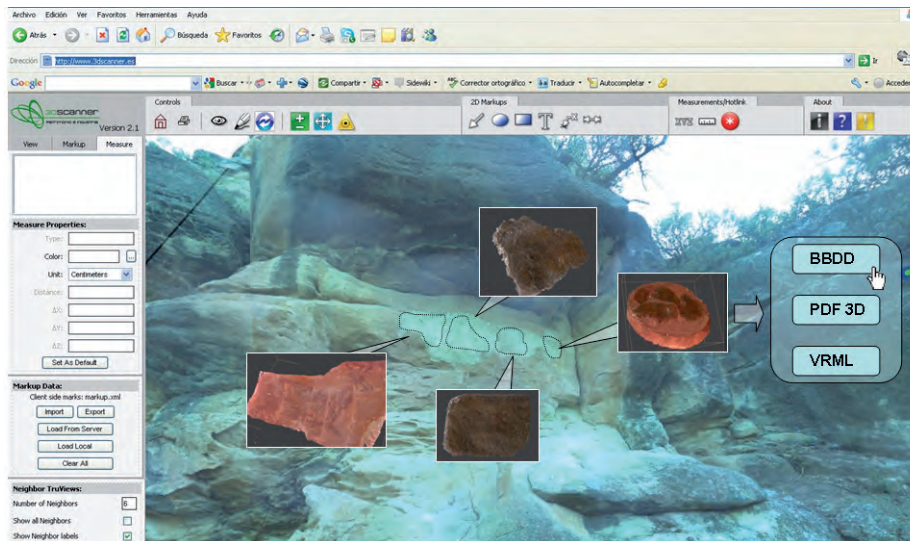


Fig. 6. Integration of Levantine rock art fragments extracted from their natural surroundings with a web data server. "Roca dels Moros" (Cretas, Teruel).

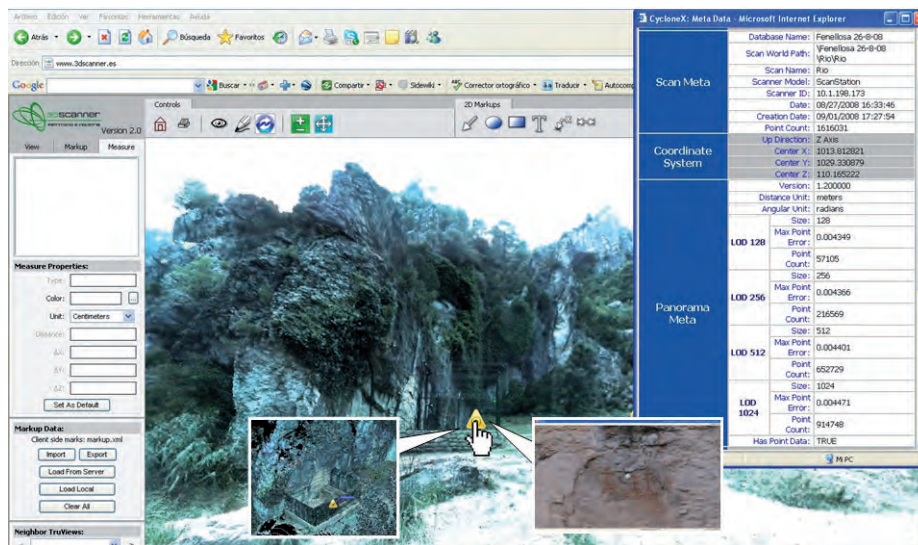


Fig. 7. Metadata, 3D model and panoramic viewer on a web data server ("La Fenellosa". Beceite, Teruel).

apart from carrying out a periodic control of the structure, preventing any kind of morphologic pathology.

CONCEPTUALIZATION OF THE APPLIED METHOD

- Record of reality. Application of the metaphoric concept of the industrial term *as built*. Interaction and comparison with recording procedures of other disciplines, ENGINEERING – INDUSTRY – ENVIRONMENTAL SCIENCES. This implies the use of a new language that will allow for the recording of reality.

- Standardization of procedures. Quality and process control through procedures. This will ease the understanding of the chain of processes that verifies the final result, so that each process in the chain may be analyzed individually (Table 1).  
 - "Democratization" to a user-level of 3D results, allowing its dissemination and spread to society. Specific conferences already exist in archaeology, focused on open code formats, such as 'ArcheoFoss 2010. Open Source, Free Software e Open Format nei processi di ricerca archeologica' in Foggia (Italy).

- Multidisciplinary methodology supervised by a specialized technician. The ultimate aim is the creation of a 'democratic' database, with the use of web environments that are easy to configure and have different access levels, in order to achieve a greater dissemination of the archaeological site, graphically, but especially geometrically. This would enable a quick and

precise viewing of any element or part of its structure. In pursuing this aim, we have achieved a greater dissemination and appreciation of the obtained information, while also contributing towards interdisciplinary scientific studies, thus solving the various existing gaps in three-dimensional methodology and conceptualization.

Target	Model 1	Model 2	State	Accuracy	Error Vector
Diana 2	arriba 1	arriba 2	On	0.001 m	( 0.001, 0.000, 0.000) m
Diana 3	Exterior	Interior	On	0.001 m	( 0.000, -0.001, 0.000) m
Diana 6	Exterior	Interior	On	0.001 m	( 0.000, 0.000, 0.000) m
Diana 7	Exterior	Interior	Off	0.093 m	( 0.080, 0.040, -0.026) m
Diana 8	Exterior	Interior	On	0.001 m	( 0.000, 0.001, 0.000) m
Diana 1	Exterior	Dianas	On	0.001 m	(-0.001, 0.000, 0.001) m
Diana 2	Exterior	Dianas	On	0.002 m	(-0.001, 0.002, 0.000) m
Diana 3	Exterior	Dianas	On	0.002 m	(-0.002, 0.000, 0.000) m
Diana 4	Exterior	Dianas	On	0.002 m	(-0.002, 0.000, 0.000) m
Diana 6	Exterior	Dianas	On	0.000 m	( 0.000, 0.000, 0.000) m

Table 1. Accuracy analysis in the 3D model. It allows the verification of the process used in the geometric recording of Archaeological Heritage.

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