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4D recording and analysis: The case study of Nuraghe Oes (Giave, Sardinia)

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ABSTRACT

The work is related with reality-based 3D modelling and monument analysis. In this project we stressed the importance to use 3D technologies as a tool to improve archaeological research and to increase the production of information from archaeological data to 4D analysis and interpretation. The object of our research is a "nuraghe", a typical megalithic monument built only in Sardinia during the Bronze Age. The building, called Nuraghe Oes, is composed of one main tower and a basement – similar to a bastion – with two smaller towers; it shows peculiar features both in the internal and the external shape and it is well preserved. This project is related with the first season of stratigraphic excavation: after this, we have performed a 3D survey of the entire monument using an integrated approach. We used a TOF laser scanner for a massive data collection of the external and some internal parts of the monument and, overcoming instrument and accessibility limits, we integrated the data using image-based modelling. All datasets have been aligned in a dedicated software in order to produce a complete mesh. After the mesh editing, the model has been textured using HDR images. The high resolution and accuracy of the 3D model allowed us to highlight interesting details in construction techniques and, together with a structural comparison with other nuraghi, to esteem the original height of the main tower. Furthermore, we performed volumetric analysis to esteem the capacity of the stones collapsed inside the main tower for making hypothesis about the ancient/original aspect. Lastly, using information collected during a visual survey of the walls and the 3D analysis, we have been able to map some structural issues of the monument, like cracks or disruptions in the stones and in the masonry. All these analysis are useful to plan further stratigraphic interventions both from time and costing points of view, and to monitor the health of the nuraghe over time.

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1. Introduction

The case study is related to a "Nuraghe", a bronze-age megalithic building. A Nuraghe is a type of monument only built in Sardinia (Italy). It symbolises Sardinia and its distinctive culture,

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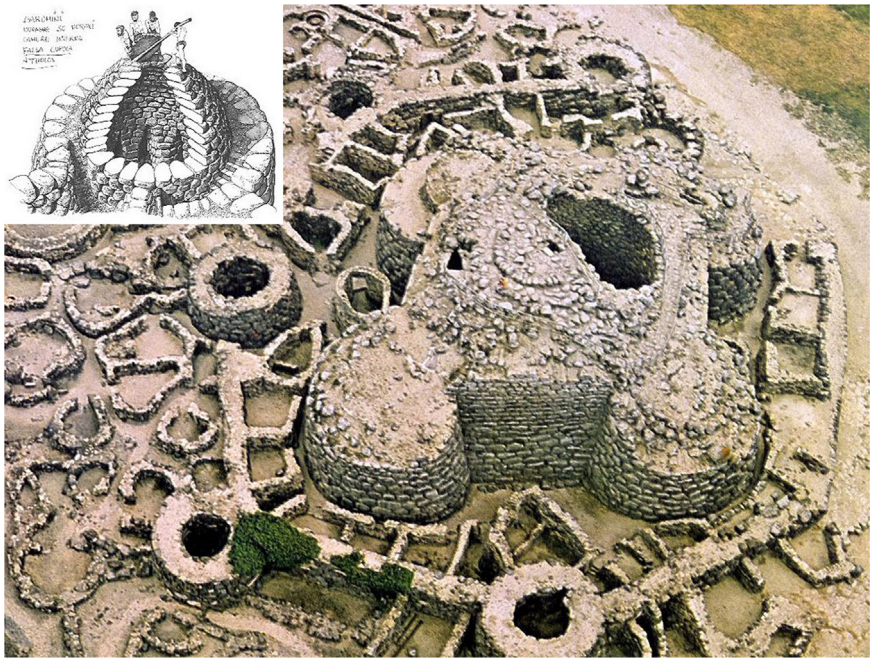

Fig. 1. Nuraghe Barumini and a drawing of Francesco Corni showing the corbel vault.

the Nuragic Civilisation, developed between XVII and VI BC.

As we can see in the Fig. 1, a nuraghe is a building made of huge stones and can have either one tower or multiple very complex towers, as does the most famous nuraghe in Sardinia, the Nuraghe of Barumini (an UNESCO World Heritage Site) which is composed by five towers and a nearby village of 50 circular huts.

In the most common type of nuraghe, the towers have internal rooms, one above the other, built with a *corbel* vault, similar to the Greek *tholos*.

A nuraghe has the function to control the surrounding territory, but each nuraghe has a different architectonic structure (one tower or multiple and complex towers) depending on the context, the geographic position and the chronology.

1.1. State of the art

The 3D recording is characterized by several methods and techniques used in relation to specific needs, without a systematic use procedures. Nowadays the most common techniques used for 3D modelling are based on terrestrial laser scanner (range-based method) and photogrammetry (image-based method), in single or integrated use. During the past decade different research groups tested the advantages and disadvantages of both approaches[1]. Laser scanners have been tested within various archaeological projects and the possibility of recording excavations and buildings in three dimensions has attracted great interest amongst archaeologists. Today the use of laser scanning can be considered a proven technology whose precision in the process of data modelling has been widely declared and verified in the field. However, the use of this instrument for archaeological purposes it is still sporadic, due to high cost of instrumentation, along with the inherent complexity of the processing and management of data.

In recent years, however, the advent of photogrammetric software based on multi-image photogrammetry (Structure from Motion) has gradually made three-dimensional digital recording accessible and practical within the documentation process to archaeologists. New processing algorithms of image matching allow to obtain image-based surface models in automatic or semi-automated way with an accuracy and detail level that can be surely compatible with 3D scanner clouds in terms of point density and accuracy (Fassi et al., 2013). In the last years, the availability of commercial packages software that automate the restitution process of images is creating a sort of revolution in cultural heritage; it is making faster their use as well as more accessible to largest users, allowing archaeologist to directly manage the acquisition and processing tasks.

In several projects has been used the integration of sensors and data (multi-sensor data fusion): the combination of the methods is considered a good solution where each technique has attributes and elements that balance one another, in particular when surveying large and complex sites. (Gonizzi Barsanti et al., 2012; Fassi et al., 2013; Guidi et al., 2008; Remondino et al., 2009; Remondino, 2011b).

In Sardinia, the use of 3D recording in archaeological sites is quite rare. In fact, traditional "bi-dimensional" survey is still the most common approach to produce the documentation of archaeological sites or buildings, especially in a prehistoric contest.

When the Project of Nuraghe Oes started in 2012, the 3D recording methodology was one of the first applications in Sardinia that allows to obtain detailed graphic documentation of the state of the nuragic monument and make 3D/4D analyses increasing the knowledge process about the megalithic building. We optimised the 3D documentation process using both photogrammetric and laser scanning techniques. In fact, as previously said, the integration of various geomatic techniques is nowadays an important requirement to produce complete 3D models.

In 2012, the 3D metric survey of Nuraghe Tanca Manna (Nuoro) has been also developed during the archaeological excavation of the site (Fiorini, 2013). As in our research, Tanca Manna 3D survey follows the same idea to make a scientific and detailed documentation of the monument for its study and analysis. For the study of Nuraghe Tanca Manna, a photogrammetric approach has

[1] For recent researches e.g. Arrighetti and Cavalieri, 2012; Benedetti et al., 2010; Caldarelli et al., 2012; Callieri et al., 2011; Campana et al., 2008a; Campana and Remondino, 2008b; Campana et al., 2009; Campana et al., 2012; Campana et al., 2014; D'Andrea and Barbarino, 2012; Forte et al., 2012; Gonizzi Barsanti et. al., 2012; Neubauer and Doneus, 2008; Panella et al., 2011; Peripimeno, 2009; Remondino and Rizzi, 2010; Remondino, 2011a; Remondino, 2011b; Russo et al., 2011. For a *summa*: Campana and Remondino, 2014; Cowley and Opitz, 2013.