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Original
3D hight accuracy survey and modelling of one of aosta's anthropomorphic stelae / Bornaz, L.; Porporato, C.; Rinaudo, F.; De Gattis, G.; Focareta, R.. - In: INTERNATIONAL ARCHIVES OF THE PHOTOGRAMMETRY, REMOTE SENSING AND SPATIAL INFORMATION SCIENCES. - ISSN 1682-1750. - STAMPA. - 36:5/C53(2007), pp. 176-181.

Availability:
This version is available at: 11583/2764442 since: 2019-10-30T16:51:26Z

Publisher:
International Society for Photogrammetry and Remote Sensing

Published
DOI:

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12 October 2024

3D HIGHT ACCURACY SURVEY AND MODELLING OF ONE OF AOSTA'S ANTHROPOMORPHIC STELAE

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KEY WORDS: Cultural Heritage, Archaeology, Archiving, Recording, Close Range, High resolution, Increased Reality

ABSTRACT:

The Aosta Valley still preserves important traces of prehistoric and protohistoric settlements in the aeneolithic necropolises of Champrotard (Villeneuve), Montjovet and Vollein (Quart), partly associated with groups of rupestrian engravings. Megalithic monuments erected from the Neolithic Period to the Bronze Age have been found in the outskirts of Aosta, in Saint-Martin-de-Corléans, in a wide area that was once used for worship purposes. The Little St-Bernard Pass "cromlech" could also date back to the same age.
The Saint-Martin-de-Corleans megalithic area, on the outskirts of Aosta, was a place of worship and then of burial from the third millennium B.C. onwards, with alignments of anthropomorphic stelae, megalithic tombs and menhirs. The anthropomorphic stelae, most likely representations of gods or of ancient heroes, are reminiscent of those of the Petit Chasseur in Sion, proof of the intensity of cultural exchanges over the Great St. Bernard Pass during the whole prehistoric period.
The decorations of some stelae are at present barely visible. It is just possible to see some decorated parts using a specific shaving lighting system.
The aim of the archaeologists was to preserve the surface of the stelae by arranging them in sheltered areas. At the same time, it was very important to carry out a 3D high resolution survey of the decorated part of the stelae. The aim was to prevent the decoration of the stelae from being lose in the future.
High resolution 3D survey systems have long existed especially for mechanical applications. High resolution prototype instruments have also been developed and used in the Cultural Heritage field in order to create accurate 3D models that are able to form a basis for reproduction, restoration and conservation purposes. Different solutions have been proposed: laser distance measurements on controlled mechanical tables, self-controlled harms, stand-alone instruments, etc. Different measuring principles have successfully been adopted: laser distance measurements, structured light, laser triangulation, etc.
The common technical problems of this kind of instruments are due to the stability of the acquisition reference systems during the survey or to the need to have direct access to the object. The economic problems are due to the high costs of the instruments.
A new generation of high resolution and high precision scanners have recently been introduced: these try to solve both the previously mentioned problems. At a cost of less than the usual amount for a terrestrial scanner of low accuracy and with a direct survey in a 3D reference system materialised on the object, or nearby, these new instruments (the so-called third generation scanners) allow a complete surface of convex and concave objects to be scanned avoiding the necessity of moving the object from its natural location and without heavy instrumentation.
This new instrument, produced by CREAFORM, a Canadian Technological centre for reverse engineering and 3D digital solutions, is called HANDYSCAN 3D. This has been presented as the first self-positioned hand held scanner in the world.
The basic idea of this instruments is very simple (it is a digital photogrammetric system), but the adopted solutions represent a true novelty from different points of view in the Cultural Heritage surveying field.
The first interesting aspect is the dimension and weight of the acquisition unit which can be handled for long periods without tiring the operator and it allows the possibility of obtaining all the details, even in the case of very complex objects.
The second attractive aspect is the possibility of acquiring objects of different dimensions: from small objects (e.g. rings, fragments, etc.) to very large objects (e.g. statues, large epigraphs, etc.).
Finally, the third attraction is the price, which is lower than the current quotations of the less accurate terrestrial laser scanners, even considering the laptop for the storage and the visualisation of the acquired data.

The handling of the data can be performed using one of the well known software packages (e.g. RapidForm, 3Dmax., etc.).
The acquisition can be done by a specific dedicated software created by the CREAFORM company or using a special link made by Creaform to the Geomagic Studio which can directly manage the data from the HANDYSCAN3D system.
The accuracy of the acquired data, their flexible resolution and the real time check of the completeness of the acquisition phase are the best requirements for a quick and correct model approach.
The paper describes the acquisition phases and the obtained resuts of a 3D HandyScan Hight accuracy survey on one of the 41 anthropomorphic stelae in the megalithic area of Saint-Martin-de-Corleans, on the outskirts of Aosta. In addition, a complete photogrammetric survey was carried out in order to check the possibility applying a realistic photo mapping of the object to the acquired 3D model. Finally, the acquired 3D high accuracy model was elaborated with a 3D surface modelling process in order to check the possibility of showing the still exsisting decorations.

1. INTRODUCTION

The anthropomorphic stelae of Aosta were found in the megalithic area of Saint-Martin-de-Corleans, on the outskirts of Aosta, in 1969.

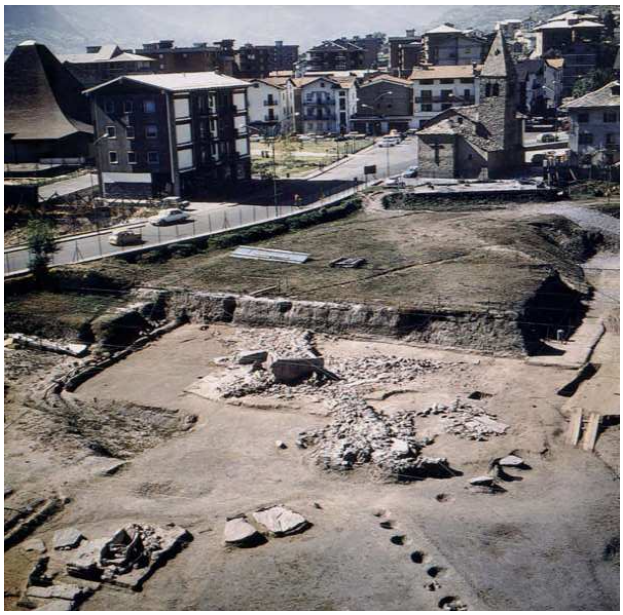


Figure 1. Megalithic area of Saint-Martin-de-Corleans, on the outskirts of Aosta

These stone representations date from the Neolithic Period to the Bronze Age, about 2500 – 3000 B.C.
The decorated surface has slowly been worn away for many reasons.

Figure 1. The anthropomorphic stelae in Aosta – The Aosta Valley (Italy) Local Arcaeological Museum

The decorations of some stelae are at present barely visible. It is just possible to see some decorated parts using a specific shaving lighting system.
The aim of this experience was to provide a realistic 3D model of the stelae and to check whether if it is possible to better understand the engravings using 3D modelling.

a)

b)

Figure 2. The anthropomorphic stelae of Aosta without and with a shaving lighting system - a) the whole stelae, b) details of the decorated surface

The amount of the decoration detail can be considered as an amount of less than 1 mm therefore, high accuracy methods and instruments that are able to acquire a huge number of points have to be used in order to check, , the geometric drawings of the stelae in a proper and affordable way. This kind of instrument are generally known as Scanning Systems.
High resolution Scanning Systems are based on different physical principles (e.g. LIDAR, structured light, holography, photogrammetry, etc.) but they are usually equipped in order to be used inside controlled laboratories and not in the field, as this application requires.
Only photogrammetry based scanning systems can offer a good solution: the reference system is fixed onto the object and not inside the acquisition unit, the geometric survey can be directly connected to the radiometric information emitted or reflected by the object itself and many automatic procedures can be used in order to speed up the acquisition phase and the generation of dense point clouds.
The instrument used during our research is an innovative photogrammetric based system which allows high accuracies and high performances to be obtained, in terms of practical solutions, both during the acquisition phase and the data treatment and it avoids some of the problems that traditional photogrammetric systems always create (e.g. control point survey, orientation of stereoscopic images, autocorrelation, etc.).

2. THE HANDYSCAN 3D BY CREAFORM

Produced by CREAFORM, a Canadian Technological centre for reverse engineering and 3D digital solutions, HANDYSCAN 3D has been classified as a third generation high resolution 3D scanner instrument. It has been presented as the first self-positioned hand held scanner in the world.
The acquisition unit contains two digital cameras mounted onto a rigid body. Four red light leds are placed around each lens and there is a special laser tracker at the bottom of the handle, which is useful during the acquisition process to mark the surveyed points.

Figure 3. Handyscan 3D: the acquisition unit (980 g, 160 x 260 x 210 mm, ISO accuracy: 20 m + 0.2L/1000)

The basic idea of this instrument is very simple (it is a digital photogrammetric system), but the adopted solutions represent a true novelty from different points of view in the Cultural Heritage surveying field.
The first interesting aspect is the dimension and the weight of the acquisition unit which can be handled for long periods without tiring for the operator and it allows the possibility of obtaining all the details, even in the case of very complex objects.
The second attractive aspect is the possibility of acquiring objects of different dimensions: from small objects (e.g. rings, fragments, etc.) to very large objects (e.g. statues, large inscriptions, etc.). Finally, the third attraction is the price, which is lower than the current prices of the less accurate terrestrial laser scanners, even considering the laptop for the storage and the visualisation of the acquired data.

3. THE ACQUISITION PHASE

Before starting the survey, the instruments have to be calibrated both as far as the geometry and the radiometry are concerned.

a)

b)

Figure 4. The geometric (a) and radiometric (b) calibrations of the HANDISCAN

The geometric calibration is performed using a special control plate which is provided with the instrument (see fig. 4a). The scope of this phase is to refine the relative orientation of the two digital cameras in order to avoid small movements of the mechanical components that occur during the transportation or due to the change in environmental conditions and so on. The geometric calibration fixes the base of the photogrammetric system and therefore the scale of the survey.
The radiometric calibration aims at setting the photographic parameters for the two camera lenses and the intensity of the laser tracker in order to speed-up the measurement process. The radiometric calibration (see fig. 4b) is performed by acquiring some parts of the object with a common texture. If the object has different colours and/or illumination conditions this procedure has to be repeated before starting the acquisition on the portion of interest.
Before starting the 3D survey, the reference system has to be fixed. Several reflective targets (small 6 mm diameter circles) are fixed to the object using an irregular mesh with sides that can reach up to 10 cm (see fig. 5).

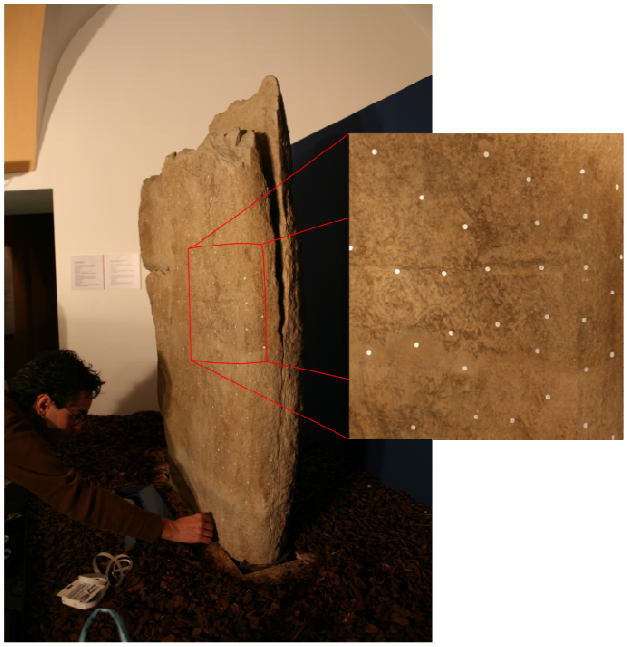
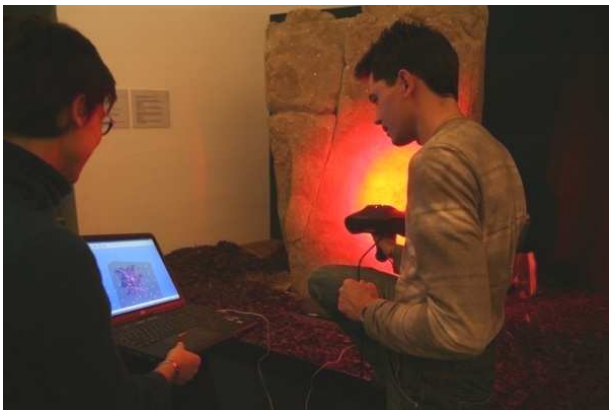
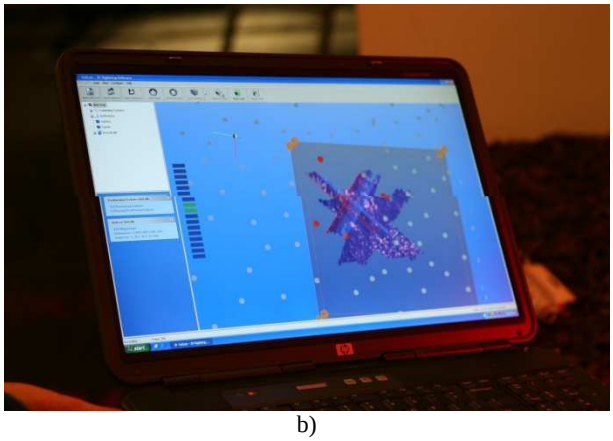


Figure 5. Placing the reflective targets on the object

Using the two stereoscopic cameras and eight spots around them, the reflective targets are surveyed and placed in a unique reference system which is now fixed onto the object. If the object cannot be marked directly, it is possible to build-up a control network using other solutions.
Finally the operator defines the volume in which the object (or a portion of it) is contained. This volume is subdivided into voxels. The dimension of a single voxel represents, in the final model, the resolution of the acquired 3D model.
It is possible to choose from among three different resolution levels: low, medium or high. For the low resolution, the surveyed box is divided into 2.1 Mega voxels; the medium into 16.8 Mega voxels and the high into 134 Mega voxels. There is therefore a ratio of 1 to 8 between the medium and low resolution voxel numbers and the same between the high and medium resolution voxel numbers. The dimension of the voxels (the resolution of the survey) depends on the dimension of the acquisition volume. If high resolution is required, the object has to be split into different scans which are oriented in the reference system of the acquisition thanks to the previously acquired reflective targets. The accuracy is always the highest accuracy of the instruments.



a)



b)

Figure 6. a) Data acquisition, b)The Handyscan sofware during the acquisition phase

In our case, the stelae's surface was subdivided into 10 portions and acquired. Nine portions were acquired with a high resolution in order to describe the decorated part of the stelae and 1 portion was acquired with a lower resolution to describe the other parts of the stelae.
Once all the settings have been completed, the acquisition can be started: the operator has to check the distance between the acquisition unit and the object (red and green leds on the top of the acquisition unit make this possible in a practical way) and, by looking at the laptop, control the completeness of the acquisition that is displayed in real time as a 3D surface model.

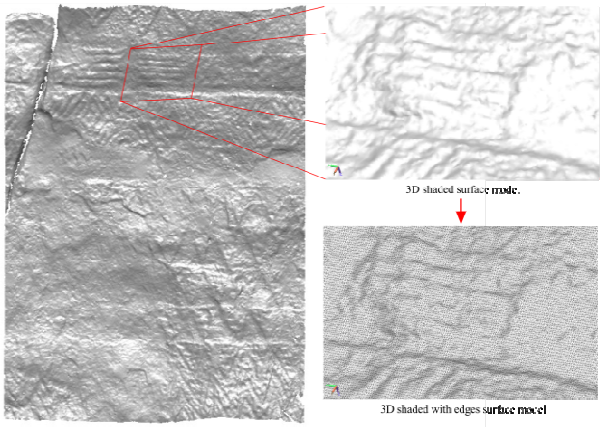


Figure 7. One of the obtained single 3D models.

During the survey, the stereoscopic cameras perform the absolute orientation using the previously acquired reflective targets. At the end of the acquisition, the recorded data are: the target positions, directly acquired points, and a binary STL format 3D model.
About 6 hours were needed to acquire the whole stelae's surface.

4. DATA PROCESSING

The acquired points were processed by using a commercial software (Geomagic) and a scientific software developed by the Politecnico di Torino DITAG research group (LSR 2004) in order to build up a 3D model of the three inscriptions.

All the gross errors and outliers were eliminated and a correct registration of the single acquisitions were performed using an original approach developed by our Research Group.

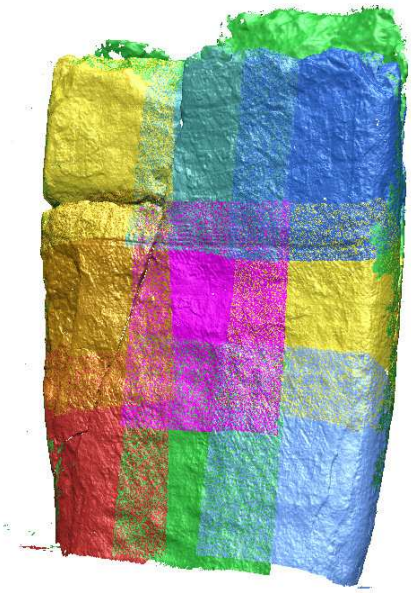


Figure 8. The alignment phase.

As there are some fractures on the surface of the acquired stelae, some holes can be found in the acquired 3D model. In order to obtain a complete 3D surface model of the stelae, all the holes were filled using geomagic software.

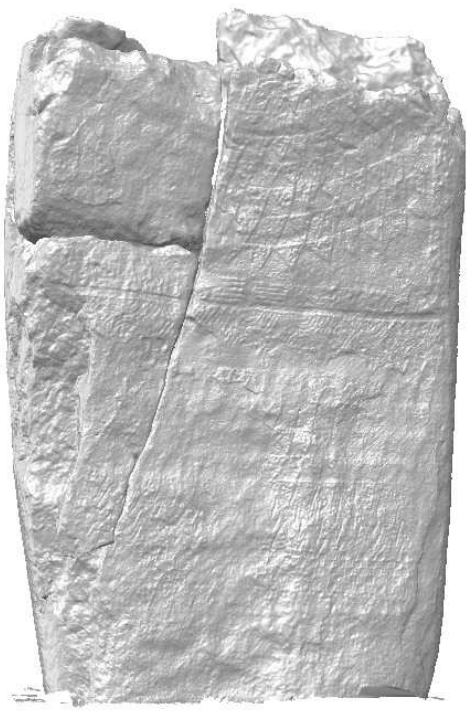


Figure 9. The final 3D model.

The final 3D model was composed of 3˙254˙339 vertices and 6˙410˙393 faces for a total surface of ~ 4 m^2.

The 3D model resolution in the decorated part was 1 vertex each 2 mm. The accuracy of the 3D model was 0.2 mm.

Figure 10. The final 3D model compared with the original one.

In addition to the scanning a complete photogrammetric survey of the stelae was performed using a Canon Eos digital camera equipped with a 28 mm lens. All the acquired images were oriented in the same 3D model reference system.

5. FINAL PRODUCTS

The realistic 3D model of the stelae was produced by mapping the oriented images onto the 3D point model after surface generation (TIN approach). This represents the most important output of this kind of survey technique and allows the specialists to carry out a complete and exhaustive analysis of the object.

A large amount of the data can in fact lead to some problems during the management of the data and require a high performing PC that is able to manage this huge amount of information (3D points and high resolution images).

Figure 11. The final rendered 3D model.

The authors, in agreement with the archaeologists from the Local Archaeological Museum, are now studying how it is possible to use the acquired high 3D accuracy model and how it is possible to use 3D modelling procedures to highlight the still exsisting decorations.

Figure 11. The final rendered 3D model (detail).

6. CONCLUSIONS AND FUTURE DEVELOPMENTS

The new generation of high resolution scanning systems can be profitable if used in Cultural Heritage documentation.
These systems allow all the problems concerning the stability of the reference system to be avoided. Not so much time is required to perform the survey considering the final results in terms of completeness and accuracy (approx. 0.2 mm).
The image acquisition and orientation is still a problem as these phases are not integrated in the 3D point acquisition process but we believe that future technology will allow this kind of integration to take place, as occurred in the field of lower accuracy scanning systems.
More research must now be carried out to study the possibility of engraving actual decorations to obtain an increased understanding of the ancient drawings.

ACKNOWLEDGEMENT

This paper has been written to remember and thank **Roberto Focareta** for his enthusiasm and scientific and practical collaboration during the acquisition and data treatment phases. It was only possible to do this exciting research thanks to his dedication to using new technologies and acquisition instruments in cultural heritage.
His humanity and friendship will always remain with us.

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