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Reading the past through digital documentation: an integrated methodological approach to the inscriptions of the Harkhuf's Tomb in Aswan (Egypt)

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***Abstract* – The project TECH aimed to document an Egyptian monument for Egyptological studies and researches but, at the same time, to check new methodological opportunity for conservation, valorisation and enhancement. In particular, the CNR mission has focused the attention on the tomb of Harkhuf, a high official of the VI dynasty (XXIII century BC), who led trading and military expeditions into Nubia. The hieroglyphic texts inscribed on the façade of his tomb are very important and famous documents. The team has checked an integrated methodology. Photogrammetry has been used to generate an accurate 3d model and to facilitate the epigraphic work. Moreover climatic measurements have been carried out. Finally the data have been crossed in order to check the environmental impact and the decay.**

I. INTRODUCTION TO THE PROJECT

The CNR – Multidisciplinary Egyptological Mission (CNR – MEM) has worked in the tomb of Harkhuf in order to document its important hieroglyphic inscriptions. The mission has been carried out in the framework of the project TECH (Technologies for the Egyptian Cultural Heritage) funded by the National Research Council of Italy (CNR) and the Academy of Scientific Research and Technology of Egypt (ASRT).

Aswan is the southern gate of Egypt: in ancient times caravan routes left the Nile Valley from this site to reach far away territories and different populations, carrying back exotic and precious goods.

The ancient city of Elephantine, the river island in the modern town of Aswan, was the gateway to Africa, the bridgehead towards unknown lands as dangerous as rich in exotic treasures.

Between the late Old Kingdom and the early Middle Kingdom, the tombs of the nobles at Qubbet el-Hawa testify of ancient journeys, far south explorations, trades and cultural exchanges, in particular, the tomb of Harkhuf, a high official of the VI dynasty, who led trading and military expeditions into Nubia [1]. The text inscribed on the façade of his tomb is a very important and famous document (*Fig.1*).

Fig. 1. The famous Tomb of Harkuf in Aswan.

Harkhuf led at least four expeditions to far away countries in the southern or west-southern territories. His tomb testifies of his life, his career, his journeys and explorations towards south, in the Nubia and in the Lybian desert. Harhkuf was a noble of Upper Egypt, he served the kings Merenra and Pepi II, during the VI dynasty in the XXIII cent. BC [1].

This tomb was at first noticed by an Italian scholar, Ernesto Schiaparelli, famous Egyptologist who discovered f.i. the tomb of Nefertary and other important monuments. Schiaparelli, who was Director of the Egyptian Museum in Florence and of the Egyptian Museum of Turin, published the inscriptions in the Memorie dell'Accademia dei Lincei in 1892 [2]. Schiaparelli was a pioneer of the inter-disciplinary Archaeology and Egyptology, and he used the photography as an instrument for documentation on the archaeological field.

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In the 1975, Miriam Lichtheim, who published a famous work on Ancient Egyptian Literature, wrote in her book: Cut in soft, flaking stone, the inscription (of Harkhuf) is now in a very poor condition. In fact, the wind, the sun and some rainfalls contribute to the decay [3].
TECH Project aimed to check a non invasive methodology for documenting Egyptian monuments and above all Egyptian epigraphy. The tomb of Harkhuf has been chosen because of its importance, its status and for the old documentation provided by E. Schiaparelli, which represented the starting point for the work.
The project aimed at a very good documentation by digital photogrammetric system in order to obtain data on its conditions, to check the decay and the influence of the environmental factors.

G.C.

II. THE SURVEY ON THE INSCRIPTIONS

The work presented in the paper is a preliminary note of a wider project on Harkuf's Tomb. Since the first survey on the site, in 2014, several and damaged inscriptions preserved on the facade and the pillars inside the tomb, have been noticed. Most of them are in different conditions, probably due to the intrinsic characteristics of the stones and to the weathering phenomenon. From the observations made during the mission emerged the importance of documenting the inscriptions, that actually risk to be lost forever. The most important inscriptions are visible on the main façade. They represent an important document of the Harkuf's life (*Fig.2*). The four pillars inside show reliefs and inscriptions with funerary formulas.

Fig. 2. The inscription preserved on the main facade of the Tomb represents an important document of Harkhuf's life

The first step was the documentation of the existing texts with a methodology that was able to record the signs and, at the same time, was able to evidence the differential degradation. Every inscription was accurately documented through the use of photogrammetric systems (image based 3d modelling). Digital photogrammetry can be considered a valid instrument of investigation and analysis to improve the knowledge in the archaeological field. In recent years the development of digital photogrammetric systems allowed to define a very accurate working protocol of data acquisition and processing in the archaeological discipline. The extraordinary development of camera sensors, the manufacturing of the lenses and the more accurate algorithms for the recognition of the homologous points on images, actually allow to reconstruct the whole investigated subject [4].
The methodology was focused on the use of photogrammetric system despite other different approaches to problem exist, such as the use of laser scanner (triangulation) or polynomial texture mapping. The use of digital photogrammetry is justified by the possibility to use a simple device (such as a camera) in every condition, collecting important information and data about cultural heritage [5]. Furthermore, due to the history and evolution of the photogrammetry, we are able to evaluate its potentiality and expansion to other application fields.
The first step of the research focused mainly on the external facades, probably subjected to a greater stress. The survey was performed using two reflex cameras (Canon 5D mark II, Canon 60D) with different optic lenses (Canon 28mm/ 50mm). The following modalities have been used:
- Visual Structure From Motion (Agisoft Photoscan);
- Stereoscopic photogrammetry (MenciSoftware);

The first system, well known as Visual Structure From Motion (VSFM), allows to perform photogrammetric acquisition starting from unordered images. We used a 28mm optic lens with a tripod at 0.50 m from the facade, moving the camera along the whole surface (*Fig.3*). We took more than 400 picture for the Harkuf's letter at very high resolution and with 80% of overlapping among the pictures.

Fig. 3. Acquisition step performed with a Canon 5D Mark II mounted on a tripod.

Simultaneously we used the same camera with the other system, based on the stereoscopic acquisition of three images. We mounted the camera on a little aluminium bar (0.70 m) on the tripod at 2 m from the inscription.

Knowing the distance among camera positions, it is possible to achieve spatial coordinate of inaccessible points. The system is often used in topography and is known as "*space forward intersection*". In the same way of the human sight, from two camera images (central projection) it is possible to define accurately each single point. The geometrical model explain how it is possible to achieve the coordinates (*Fig.4*). However the accuracy of the model depends on the angle of the collimation straight lines and on the distance of the cameras from the object.

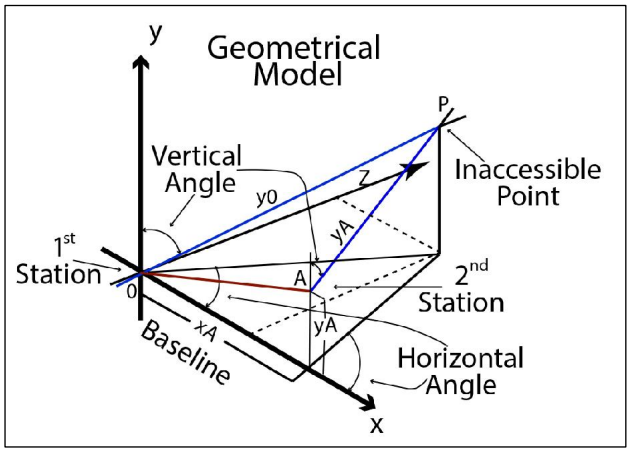

Fig. 4. Geometrical model used in topography and adopted in photogrammetry.

It is however possible to demonstrate that the collimation straight lines are twisted lines, so that it is necessary an interpolation to find exactly the point [6].
The VSFM was used to create an high resolution 3d numerical model (point clouds) even if the main problem consists in a not scaled result. The second system (stereoscopic) generated an accurate and scaled 3d point clouds. We used both the models. The second model allowed us to calculate the coordinates of the letters and transfer them to the not scaled model. The only limit of the stereoscopic system consists in the orientation of the reference system that is in the origin of the perspective pyramid of the camera. In order to solve this problem and perform the final graphic restitution it is necessary to transform the UCS in the specific software.
However the error between the two numerical models and the coordinates is 0.008 mm. This error depends mainly from the correct recognition of the points between the two models, the different definition of the images taken at different distance and the resolution step of the point clouds.

III. THE PROCESSING STEP

As mentioned above the photogrammetric survey was carried out on the entire archaeological complex but only the letter preserved on the main entrance completely elaborated.
A specific elaboration procedure was developed for the inscriptions and the results are very interesting. The processing step was performed with different software of point clouds management. The aim of the study was to create a numerical model of the inscription at high resolution and able to give information about its condition. From the high resolution 3D model (point clouds) it was possible to carry out all the measurement about length, width and deepness of the engraving and to get information about the geometry, morphology and the global visualization of the object. With the integration of different point clouds management software was possible to make a series of elaborations in order to get a better organization and comprehension of the data (Fig.5).

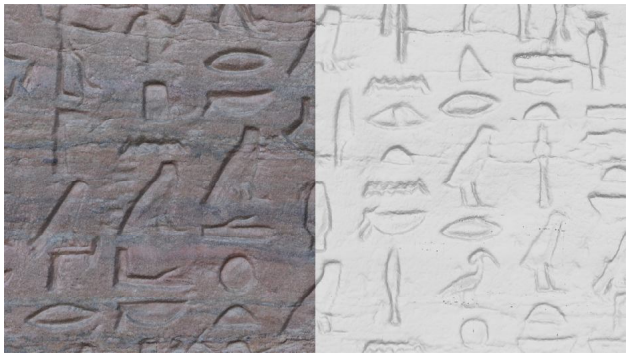

Fig. 5. From the numerical model is possible to divide the chromatic characteristics from the shape of the engravings

It is also possible to fit the model with other points and afterwards interpolate them with surfaces through the meshing techniques. This transformation is very important for the results. Normally this transformation is based on Delaunay triangulation of the points in the space. Some interpolation occurred in a second step to light the model but preserving the shape of the inscriptions [7].
In order to read the information about the conditions of the inscriptions, we decided to create maps useful to the investigation and analysis. Point clouds carried out from photogrammetry are unstructured point clouds. We processed the data with a software, JRC Reconstructor, to transform them in structured point clouds. In this way it is possible to give to the photogrammetric data the same characteristics of a laser scanner data. The tool used is named virtual scan. Once established an orthographic camera that includes the numerical model (unstructured) it is possible to acquire the whole surface at a specific resolution, such as a laser scanner information. Despite the resolution depend also from the hardware graphic card, it is possible to create a new structured 3d model of the inscription with the same characteristics of a point cloud taken with laser scanner. In this way it was possible to generate different outputs such as Digital Elevation Model (DEM), normal map and other elaborations useful for the final results (*Fig.6*).

IV. THE REPRESENTATION OF THE DATA

The aim of the work is not only to have a numerical model but also how we can use the model to draw the hieroglyphics in a bi-dimensional restitution for the epigraphists. The research group is experimenting different solutions able to solve the dichotomy between innovative acquisitions and graphic representations.

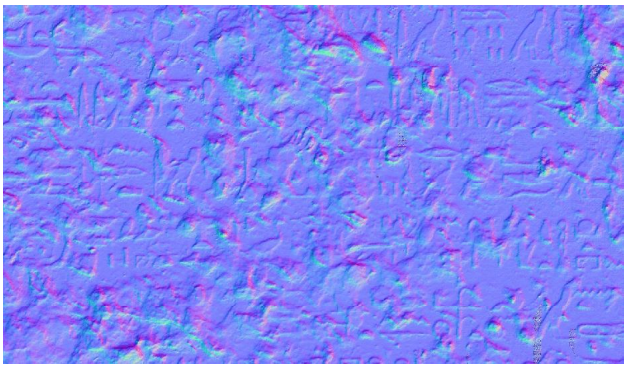

Fig. 6. Normal map of the inscriptions. It is possible to evidence the difference between casual signs and engravings

Usually bi-dimensional representations of the inscriptions are based on direct survey, supported by a photographic restitution on a specific plane (*Fig.7*).

Fig. 7. Inscriptions drew with manual recognition of the signs and probably the aid of photographic survey

Unfortunately this kind of representation does not characterize correctly signs and shape of the engravings. Aim of the project was to find a form of representation suitable for the epigraphic signs. We experimented a system derived from cartography and above all in the sculpture. The approach is based on the representation of the contour lines. Contour lines represent free shape of an object beyond contour outlines and edges of the engravings [8]. The equidistance of the contour lines depends on the representations scale of the graphic restitution. The equidistance normally is set to 1/1000 of the representation scale of the object declared in meter. The results evidenced the differences between the old drawings and the new approach. Certainly also in this approach it is necessary to establish a reference plane where projecting the representation. The signs are well defined by the lines and simultaneously the shape and the curvature of the stone material are described (*Fig.8*).

A.A.

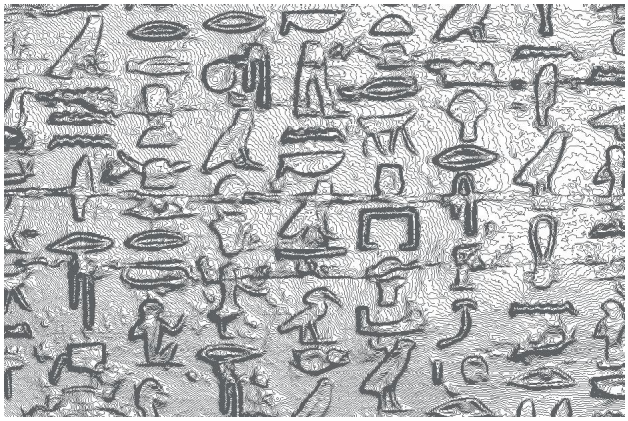

Fig. 8. The equidistanceis set to 0.0005 mm. This adaptation allows to draw adequately the inscriptions.

V. THE INFLUENCE OF THE CLIMATE

The tomb of the Nobles are carved in the rocks on the west bank of the river Nile in Aswan, an area characterized by hot and dry weather conditions [9], which are typical of a desert climate. In this region the total rainfall amount per year is about 1 mm, and heavy precipitation is a very rare event occurring once every 1 or 2 years, often resulting in flash flood. These rare, but heavy rainfall episodes have important, and sometimes catastrophic impacts, due to the high intensity and short duration, on population, buildings, infrastructures, ecosystems [10], including wadis discharge [11], and cultural heritage.

The meteorological factors affecting the tomb of Harkhuf at Qubbet el-Hawa are air temperature, its diurnal excursion, and wind, and, to some extent, relative humidity. In fact, in Aswan, night time relative humidity can be more than 30% during the winter months, which rise rapidly during heavy rainfall episodes. The experiment, designed using portable meteorological instruments, permitted to define if the microclimate around the Harkhuf Tomb has the same characteristics of the larger Aswan area, which can be derived by the meteorological station located at the Aswan airport, and to determine the microclimate inside the tomb. In particular, it contributed to:

- determine the temperature gradient along the façade of the tomb in order to understand if the different parts of it are under the influence of physical stress of different intensity;
- determine if temperatures excursion together with the right level of relative humidity of the air could favor the

formation of dew at dawn and if the air can reach high dew point values.
Preliminary analysis of data collected between 8:00 am and 4:00 pm local time (*Fig.9*) permitted to detect a differential heating of the façade, with the right part reaching temperatures warmer (few degree C) than the left and for a longer period, being under the direct sunrays until early afternoon.
In the interior, during the day, the temperature excursion is much more moderate.
In addition, some measurements of wind intensity and direction show a persistent wind blowing from N-NE starting mid-morning, around 10:30 am until late afternoon.
Relative humidity outside the tomb is not a big issue during the day, however it is important in the interior where it can reach larger values and maintain a risky level during nighttime which can favor the formation of mold on the ceiling.

M.B.

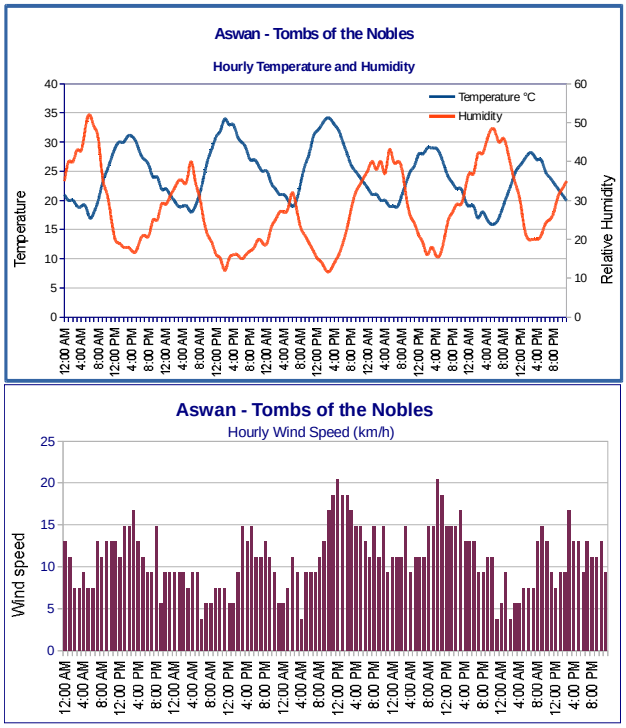

Fig. 9. diurnal variation of temperature and relative humidity (top panel) and of wind speed (bottom panel)

VI. CONCLUSION

The integrated methodology applied to the Harkhuf's tomb has given good results. The team is elaborating the data in order to render an accurate documentation, and to plan a conservation and restoration project.

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