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Multimodal 3D digitization of the megalithic complex of Borġ in-Nadur (Malta): an archaeoastronomical perspective

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Abstract – **The Maltese archipelago is home to megalithic structures of extraordinary interest for archaeo-astronomy. Some of those impressive prehistoric complexes have revealed significant architectural and topographic features reflecting a certain knowledge of the celestial bodies and astronomical phenomena by their ancient builders. While previous archaeo-astronomical studies of these Neolithic structures were primarily based on traditional methods, this paper presents an innovative approach for the case study of the Borġ in-Nadur site. Through an ensemble of techniques, such as terrestrial laser scanning, aerial and terrestrial digital photogrammetry and 3D modeling, the prehistoric remains have been 3D digitized and inserted in a virtual environment to test archaeo-astronomical hypotheses via computer simulation.**

I. INTRODUCTION

The site of Borġ in-Nadur, set on a hill overlooking St George's Bay, comprises two different areas, the Bronze Age fortified village on the top of the hill [1] and the megalithic structure (Fig. 1) on the eastern slope that, was in part reused and modified throughout the Tarxien and Borġ in-Nadur periods [2].

Fig. 1. Borġ in-Nadur Neolithic complex

II. MULTIMODAL 3D DIGITIZATION

In October 2022, a multimodal remote sensing survey was carried out at the prehistoric megalithic structure of Borġ in-Nadur, located in Birzebbuġa (Malta). The primary aim of the work was to develop an overall topographic and digital archaeological survey of the site employing terrestrial laser scanning (via Faro Focus M70), and aerial and terrestrial digital photogrammetry (via UAV Phantom DJI Pro V2.0 and DSLR camera Canon EOS 2000D). All phases of the work were also documented through photographic images and videos and recorded by drone and digital video camera, for the creation of future content for public outreach purposes.

Fig. 2. Phases of the remote sensing survey.

A. Terrestrial laserscanning

After an initial technical survey of the area, the 3D data collection was initiated focusing on the entire perimeter of the archaeological remains and parts of their interior. The 3D digitization was conducted via Faro Focus M70, capturing 26 scans with high resolution (43.7 mpt, 10240 x 4267 pt, 6.1 mm/10 m) (Fig. 3). The processing of the raw data was carried out employing Autodesk Recap Pro

2023, resulting in a 3D point cloud model of 465.315.304 points (Fig. 4).

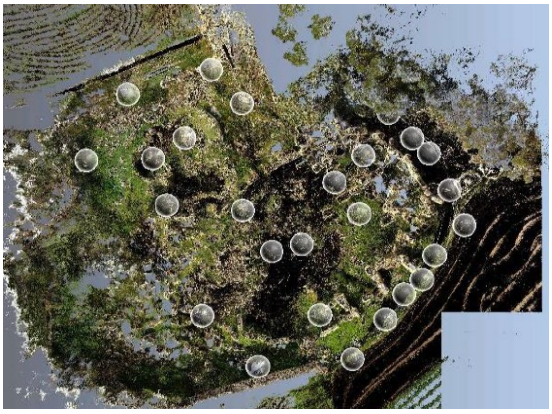

Fig. 3. 3D point cloud with indication of the 3D scanning stations.

Fig. 4. 3D point cloud model of the Neolithic remains.

B. Aerial digital photogrammetry

With regards to aerial digital photogrammetry, the dataset created with UAV Phantom DJI Pro V2.0 comprised 500 photos, taken at 8m of height and with a resolution of 4864 x 3648 pixel, and size of 8.8 mm 2.61 x 2.61 µm (Fig. 5). With this dataset it was possible to create a 3D model, with a dense cloud of 70,159,405 points, employing Agisoft Metashape and 3DF Zephyr (Fig. 6). Subsequently, via GPS, the 3D model was georeferenced and orthophotos of the site were generated from it and then imported in QGIS to create an updated topographic plan of the entire site. For georeferencing and positioning of the topographic plan the reference system EPSG: 23033 - ED50/UTM zone 33N – Projected was used. From the 3D aerial photogrammetry model, a digital elevation model (DEM), with a resolution of 2.15 cm/pix, and point density of 0,217 points/cm² was extrapolated (Fig. 7).

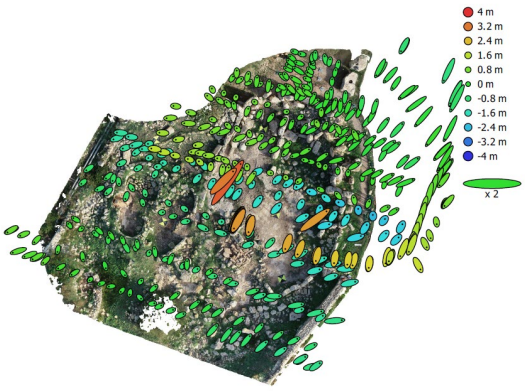

Fig. 5. Drone camera locations and error estimates, Z error is represented by ellipse color. X,Y errors are represented by ellipse shape. Estimated camera locations are marked with a black dot.

Fig. 6. Overall 3D model of the Neolithic remains.

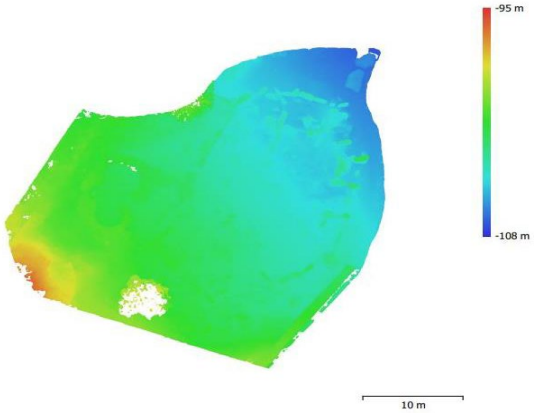

Fig. 7. DEM of the Neolithic remains.

C. Terrestrial digital photogrammetry

The survey of the whole area was carried out using a Canon EOS 2000D DSLR camera. 27 individual archaeological features, megaliths and other features of interest were 3D captured (Fig. 8). Photographs were taken with a resolution of 6000x4000 pixel (density 72 dpi), 24 Bit sRGB, for a total of 1150 images. The processing was completed using Agisoft Metashape. 3D models were disseminated via the University of South Florida's Institute for Digital Exploration – IDEx Sketchfab account, where a dedicated collection was established:

https://sketchfab.com/usfidex/collections/borg-in-nadur-2022-02b71c7eeb994603a94ad3fbb39083f6
Additionally, an annotated 3D model of the site with hyperlinks to the individual 3D representations of the 27 architectural features was produced to be used an analysis tool: https://skfb.ly/oHEoD

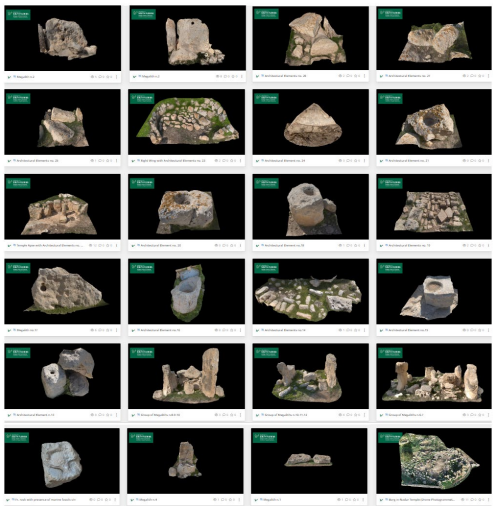

Fig. 8 Sketchfab collection with 3D models of the individual megaliths

III. VIRTUAL SIMULATION

To compare the spatial configuration of the structure, features and location of certain peculiar megaliths with sunrays projection over a whole cycle and test hypothetical relations, a simplified and retextured 3D model of the structure was placed in a 3D modelled environment (Fig. 9). Such "visualscape" [3] has been created producing a DEM of the structure's terrain from extruded multi-layered plans containing information about orography and high-resolution aerial pictures of the Marsaxlokk Bay area [4].

Fig. 9. Virtual interactive model of the Borġ in-Nadur structure

The study of the sun-light sources was carried out simulating a complete cycle of the sun on mid-summer day using the Radiance raytracer (http://radsite.lbl.gov/radiance.

IV. DISCUSSION

While the testing of the virtual simulation platform is still ongoing, the 3D digital assets produced are already able to provide some additional archaeo-astronomical insights that move beyond what is known about Borġ in Nadur [5].

Using Sky Safari 6 Pro Software, setting the location (Latitude: 35° 49' 49.0" N, Longitude: 14 ° 31' 45.0" E) and the elevation (56 meters) of Borġ in-Nadur, various potential alignments were tested for key dates such as the winter and summer solstice (Fig. 10). It was observed that at the winter solstice (December 21, 2,500 BCE at sunset (5:01:30 PM)), the Constellation of Orion appears above the Horizon at approximately 125° from true north, which is the azimuth of the central axis of the apsidal structure, suggesting that the entrance to this structure served as a potential window of visibility for these stars, including the stars of Orion's belt.

It is possible that ancient ritual practitioners who were occupying the central niche could also observe the rising of Orion at sunset on the winter solstice. The same set of stars would also be observable from this position to rise above the horizon on the summer solstice (June 21, 2,500 BCE) at sunrise (approximately 5:38 AM).

Fig. 10. Winter solstice alignment of the Constellation of Orion at sunset determined by Sky Safari 6 Pro, incorporating the 3D Model of the Neolithic complex.

Whether this was intentional or coincidental cannot be determined; however, it is curious that three stones are found within the central niche of the apsidal structure, a unique feature that cannot be found in other contemporaneous megalithic complexes. Whether these features represent the deity of the structure, as has been speculated by Margaret Murray, or are symbolic connections to the three stars in Orion's belt cannot be certain. What can be reasonably concluded is that the current position of these three upright stones is in the

same position in which they were found, *in situ*, during the original excavation in 1923. It was noted that the northern upright stone is visible from the entrance to the apsidal structure while the other two stones cannot be seen until one reaches the pitted stone separating the eastern and western apses [6]. It does not seem that the upright stones were arranged to mimic the arrangement of the stars in Orion's belt. Further modelling and testing of the alignments of these three upright stones, along with other features found in the Borġ in-Nadur structure, may prove helpful to shed light on the relationship of these curious features with that of potential astronomical alignments.

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