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Harbor of the Pharaohs to the Land of Punt II

Archaeological Investigations at Mersa/Wadi Gawasis, Egypt, 2006-2011

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dence of a possible beach environment. In this case it was important to assess the altimetry of this particular area also in relation to the test pit's geological stratigraphy. The positioning of these pits was carried out by taking their elevation (relative to sea level) into account.

The final phase of the topographical fieldwork was the acquisition of elevation points in the coastal area where there were tumuli/shrines along the northern side of Mersa Gawasis. These measurements will enable further advancement of the general topographic map of the area.

2.6 Laser scanning technology application

ANDREA D'ANDREA AND GIANCARLO IANNONE

2.6.a Laser scanning, 2007-2008

In the 2007-2008 field season laser scanning technology was applied with the support of the Centro Interdipartimentale di Servizi di Archeologia (CISA), UNO, Naples, to generate a detailed 3-D model of the western terrace wall, where Caves 2-5 were located, and the inside of Caves 2 and 3 in order to provide a proper reconstruction and plan of these caves, as well as a more precise assessment of the preservation and stability of these features for a future consolidation project. An Imager 5005 3-D scanner manufactured by Zoller & Frolich was used. The software JRC 3-D Reconstructor was used to generate 3-D reconstruction of the images.

Procedure, 2007-2008

The procedure required four days of fieldwork and four weeks of analysis and elaboration of the scanned images. Targets were applied to the outside and inside walls of the caves, paying much attention to place the targets in intermediate locations between the different surfaces in order to obtain one geometric reconstruction of all shots. On the whole, 15 shots were made (5 for the outside coral terrace wall, 4 in Cave 2 and 6 in Cave 3). Each target was also mapped with TLS to georeference the whole reconstruction. Finally, digital photos of the surfaces were used to calibrate the images produced with the scanner.

The last phase of the data elaboration was a 3-D model in movement in order to show the plan and profiles of the structures from different perspectives (Figures 26, 27, 28).

Results, 2007-2008

A relevant result is the elaboration of simulated horizontal and vertical cross plans, which can provide useful information for future work in the caves.

2.6.b 3-Dimensional models with laser-scanner, 2009-2010

During the 2009-2010 field season a laser-scanning survey of the western wall of the coral terrace at Wadi Gawasis was continued, which began in 2007-2008, in order to generate more detailed 3-D models of both the outside wall and the man-made chambers and galleries excavated into it. The survey was conducted over a length of about 64 m, and included a new laser-scanning of Caves 2 and 3 to complete the previous models of these caves, as well as the first scanning of Cave 5 where the rope coils were stored.

Ten scans were made along the external wall, at a distance of 6 m from each other and 3-4 m from the surface of the wall, using 15 targets on the wall to maintain their alignment. Eight scans of the upper part of the coral wall were also made with 10 targets at about 8 m apart, over an area of 60 m × 20 m.

Two scans were made in Cave 2 with 5 targets at about 3.8 m apart, covering an area of 24 m × 5 m (120 m^2). Two scans were made in Cave 3 with 4 targets 4.3 m apart, over an area of 15 m × 5 m (60 m^2).

Three scans with 9 targets were made in Cave 5. Because of the ropes stored in the cave, the laser scanner could not be placed on the floor of the cave and 2 scans with 5 targets along the walls between Caves 2 and 5 were made in order to link the model of Cave 5 to Cave 2.

Finally, at Cave 8, 3 scans were made outside, with 11 targets 4 m apart over a surface of 25 m × 5 m (125 m^2); and 2 scans were made inside, covering an area of 6 m × 4 m (25,23 m^2).

Registration

Because it was not possible to directly link all scanned areas, due to the great distance (over 80 m) between Cave 2 and Cave 8, some targets inside Caves 2, 3, 5 and 8; outside Caves 2, 3 and 5; and on the top of the terrace were recorded by Stefano Tilia with the total station and geo-referenced according to the absolute coordinate system. The geo-referenced points were used to align all scans in order to generate a complete geo-referenced model of the area.

Post-processing phase

All scans were filtered to reduce noise, pre-registered, aligned an geo-referenced. At the end of this alignment process the estimated mea error was below 1 cm. Finally, all point-clouds were transformed in mesh to extract plans and sections of the scanned structures.

2.7 Robotic inspection of Caves 6 and 7

HOWIE CHOSET

A robotic inspection of Caves 6 and 7, which are too unstable for humans to enter due to fear of collapse and thus are well suited for robotic exploration, was conducted in January, 2011 by Howie Choset (Carnegie Mellon University) to test a prototype of snake robot for archaeological investigation.

These robots are highly articulated mechanisms that can thread through tightly packed volumes reaching locations that people and machinery otherwise cannot (Figure 29). Their ability to move through a myriad of terrains suggests that snake robots have the potential to explore tombs, buried aqueducts, and pyramid passageways that are too small for people to enter. Once in a void space, the snake robot can move about with minimal disturbance to surrounding areas, through rugged terrain traversing distances over 150 meters. The snake robots consist of sixteen identical single degree of freedom modules arranged in a serial chain. The robot, approximately 91.5 cm long by 5 cm in diameter, moves by changing its body shape to push off the environment.

Unlike the robot used in the Giza pyramids, the snake robot can look around corners, pass through many holes and cracks, and access regions rigid mechanisms cannot. An on-board camera, with its own lighting, can return images from remote dark void spaces providing views which are otherwise unobtainable. These robots can also be fitted with water protective skin to pass through volumes containing water.

The snake robot was deployed to explore the caves (Caves 6 and 7) by having one person lay in front of the entrance to insert the robot and then manage the tether (Figure 30). The robot entered the first cave (Cave 6) and explored areas mostly in view from the entrance (Figure 31). At some points the robot was able to see parts of the cave not visible from the entrance, but no artifacts were found. It was clear from the view

Figure 26. *Longitudinal cross-profile of Caves 2 and 3 with laser-scanning technology.*

Figure 27. *Axonometric view of Caves 2 and 3 with laser-scanning technology.*

Figure 28. *Map plan of Caves 2 and 3 with laser-scanning technology.*