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The Future of the Past: From Amphipolis to Mosul, New Approaches to Cultural Heritage Preservation in the Eastern Mediterranean

Konstantinos Chalikias, National and Kapodistrian University of Athens, *Maggie Beeler*, Bryn Mawr College, *Ariel Pearce*, Temple University, and *Steve Renette*, University of Pennsylvania

The following volume comprises a representative sample of current scholarship reflecting various issues presented at the conference *The Future of the Past, From Amphipolis to Mosul*, which took place at the University of Pennsylvania Museum of Archaeology and Anthropology from April 10–11, 2015. Our initial goal was to publish all the outstanding research papers presented at the conference, but due to previous publication commitments by several authors, this volume presents instead a sample of papers that cover diverse issues, from cultural diplomacy to three-dimensional modeling of cultural heritage sites.

The conference title was inspired by two sites that monopolized many media outlets in 2014, Amphipolis and Mosul. Both sites reflected the recent challenges that cultural heritage practitioners were facing when dealing with the dissemination of information, the conservation, management, but above all the protection of cultural heritage in the eastern Mediterranean and Middle East. Although the excavation and presentation of the monumental tumulus at Amphipolis was never extensively discussed during the conference, the site and the media coverage it received played an important role when outlining the objectives of this meeting. The discovery of the elaborate tomb in Amphipolis generated excitement for the Greek public, and the site became a locus of national pride and cultural identity. The project was officially “adopted” by the Samaras government (2012–15) in an attempt to mask the harsh reality of a struggling cultural heritage agency during a period of economic austerity in Greece. On a more dramatic note, the shocking news of the devastating destruction of several sites around Mosul, including the tomb of Prophet Jonah, the sites of Nimrud and Hatra, and the archaeological museum of the city, left us wondering how helpless we were in regions that were particularly affected by political instability and war. This is not a recent phenomenon nor is it limited to the Middle East; the destruction of sites in Libya, Mali, and Afghanistan demonstrated our inability to protect our collective heritage in regions where archaeological sites became victims of conflict and “cultural genocide.”

The Future of the Past sought to bring together graduate students and emerging scholars from various academic disciplines to present new avenues in the field of cultural heritage. Our hope was to engage scholars in an intellectual dialogue, encouraging future cultural heritage practitioners from different disciplines to endorse new approaches and technologies to cultural heritage preservation in their respective fields. We were particularly interested in exploring the eastern Mediterranean, including Greece, Turkey, the Middle East, and northern Africa, regions that have been recently affected by armed conflict, political instability, and economic hardship. These are areas where we have been living and working for years, each one of us dealing with various issues such as community outreach and cultural heritage preservation. Participants to the conference were and are actively engaged in projects across the eastern Mediterranean and the Middle East, ranging in nature from the political dynamics of cultural heritage on the island of Cyprus to the use of social media in tracking cultural racketeering in Egypt, from digitization of massive datasets from the excavations at Ur to the use of satellite imagery in the documentation of recent cultural heritage destruction in Iraq and Syria. The regional and methodological diversity of these projects highlighted the far-reaching importance of cultural heritage preservation issues.

The conference was prompted also by a number of similar events in the United States and abroad, advocating a more active role for heritage professionals who, in the light of the recent developments in the Middle East, are facing something of an identity crisis. Since our conference in April 2015, we have seen numerous academic and other non-profit institutions, responding to the urgent call to act fast, to act now; to “go do good” as our colleague Morag Kersel encouraged cultural heritage practitioners in her keynote speech. The Million Image Database by the Institute for Digital Archaeology (a collaboration between Harvard University, the University of Oxford, and Dubai Museum of the Future), the CyArk initiative for the digital recording of cultural heritage around the world, the conference *Erasing the Past: Da’esh and the Crisis of Antiquities Destruction* at Wellesley College in September 2015, the workshop “Evidence and Emergency Responses to Cultural Heritage Destruction in the Middle East” at the 2016 Archaeological Institute of America Annual Meeting, and the

This event would not have been possible without the logistical and financial support of our institutions, including the Penn Museum, the Center of Ancient Studies and the Department of Art History at the University of Pennsylvania, the Department of Art History at the Tyler School of Art at Temple University, the Department of Classical and Near Eastern Archaeology, the Graduate School of Arts and Sciences, and the Graduate Group in Archaeology, Classics, and Art History at Bryn Mawr College. We are particularly indebted to the Penn Cultural Heritage Center for its technical, logistical, and generous financial support, and are especially grateful to Professor Richard M. Leventhal, who offered his guidance and assistance throughout this process. Further, we are thankful to the Archaeological Institute of America, and the Heritage, Conservation & Archaeology series for offering us a platform to publish the proceedings of this conference, and Ben Thomas, Director of Programs, who worked tirelessly for the preparation of the final manuscript. Finally, our many thanks go out to all the conference participants and contributors of this volume who shared their research with us.

recent symposium “Beyond Destruction: Archaeology and Cultural Heritage” at the University of California, Berkeley, are just a few of the initiatives that show how pressing an immediate response is to the senseless destruction of cultural heritage in the Middle East and elsewhere around the world.

Many of us who work and conduct research in the eastern Mediterranean return at the end of an excavation campaign or survey season to our respective institutions without developing a strong bond with our local counterparts who are, after all, responsible for the well-being of these sites. Public outreach and community engagement were the main themes of several conference papers, including the very promising but to this date uncertain collaboration between Boston University and Mosul University presented by Allison Cuneo, and the participation of local stakeholders in the management and preservation of urban and rural cultural sites in Turkey presented by Emily C. Arauz (neither are included in this volume). It is our strong belief that interacting with local communities regarding the value of their cultural treasures and treating them as equal partners is the first step toward a sustainable, constructive relationship that stands to benefit the preservation and protection of archaeological sites in these regions. It is our responsibility to share our experiences, our archaeological research, our finds, with the local communities in a positive and engaging way. Restricting access to the results of archaeological research impedes attempts to protect our cultural heritage, as it reinforces the public perception of academia as an elitist, secretive, bureaucratic, and dysfunctional ivory tower.

Further, in discussing the loss of cultural sites in our modern world it became apparent that we need to reconsider our priorities when designing research agendas in the selection of archaeological projects. We still measure the value of a prospective archaeological excavation in terms of the unique state of preservation of the site, its size and wealth during antiquity, and its ability to advance our professional trajectories. We almost never formulate our project goals based on the site’s vulnerability due to large-scale agricultural activities, industrial installations, and modern settlement expansion. We therefore strongly encourage and support initiatives that promote the documentation and detailed recording of cultural landscapes as a whole, even if sometimes that means that we have to abandon the idea of excavating a promising site in order to preserve the cultural landscape of a region. We need to abolish the notion that archaeologists care only for a particular artifact, site, or time period but that we are aware of the necessity to embrace and protect landscapes beyond the confines, borders, and limitations of our academic institutions.

The advent of digital humanities is a blessing for our disciplines and a large number of papers in this conference addressed the use of new technologies such as laser scanning, remote sensing, and satellite reconnaissance, demonstrating a recent trend in cultural heritage agencies. These technologies, however, are very effective when coupled with a concise research agenda. As Kathryn Hanson’s paper demonstrated, high-resolution satellite imagery may be the only way presently to document and publicize the large-scale, deliberate

obliteration of cultural sites in embattled regions of Iraq and Syria. Such technological applications are needed today more than ever in light of the devastating effects of armed conflict, and the grave dangers that archaeologists encounter in war zones around the world. Further studies presented in this conference included the use of three-dimensional modeling in architectural documentation on the isolated island of Pseira by Miriam Clinton or the photogrammetric three-dimensional documentation of a Venetian fort in Herakleion, Crete, by Gianluca Cantoro, Vasiliki Sythiakakis, and Stelios Maniouloudis. Three-dimensional digital models of archaeological sites are frequently used by educational institutions as a means of presenting complex large datasets to a wider audience, and to a degree such computational tools are used as a way to keep such institutions relevant with the most recent trends in digital humanities. The above-mentioned case studies demonstrate that the use of such non-invasive methods should become the priority in areas where archaeologists are struggling on the ground, facing outdated bureaucratic policies that limit the amount of excavation and survey permits issued each year.

We viewed this meeting as a platform for a multidisciplinary approach to cultural heritage preservation and urged all participants of this conference to forge new relationships, foster existing partnerships, and collaborate on new projects with the aim to protect the cultural heritage of the eastern Mediterranean, regardless of their academic discipline, institutional affiliation, and area of study. As one will notice throughout this volume, there are numerous ways to get involved, to respond to the call to action by Morag Kersel, to do good individually and collectively, and to rightly become “archaeo-activists” as our colleague Katie Paul encouraged us.

Visualizing Structural Issues Through Photogrammetric 3D Documentation of Cultural Heritage: the Venetian Sea-Fortress at Herakleion, Crete, Greece

Gianluca Cantoro, Institute for Mediterranean Studies (IMS-FORTH), Vassiliki Sythiakakis, Ephorate of Antiquities of Herakleion—Hellenic Ministry of Culture, and Stelios Manolioudis, Independent geologist

Abstract

Archaeological sites, monuments, and associated works of art are frequently fragile and sometimes evanescent. A three-dimensional (3D) digital model of a historic monument in its current state ensures that even if the physical structure disappears or changes, a digital copy will remain for future observation and analysis. Beyond the important documentation aspects of 3D digital models, scanned datasets also have an obvious visual appeal that engages audiences. By scanning an object or a site, the digital version can be easily revisited, visualized from any angle or direction, and shared with others. It can be edited and reused for virtual reality reconstructions and simulations. It can even be printed using a 3D printer at the desired scale and with the desired material. A priceless source of information for researchers is the point-cloud and the possibility it gives to extract precise measurements at any time, such as point-to-point distances, cross-sections, volume, perimeter, and surface area calculations.

The case study presented in this paper to demonstrate the above points consists of the 3D digital documentation of the formidable fortress on the western pier of Herakleion (Crete, Greece) harbor. Its current name, *Koules*, is derived from the Turkish name *Su kulesi* (although it was built under Venetian occupation). The fort is in the shape of an irregular rectangle, the structure of which, digitally recorded on the exterior facade, consists of strong walls from 7 to almost 9 meters thick.

Introduction: The Venetian Fortress

The focus of this paper is the photogrammetric documentation of a monumental building situated along the northern coast of Crete, in Herakleion, the modern capital of the largest Greek island. The building, a Venetian fortress (*Fortezza* or *Rocca al Mare*, according to the Venetian name) which was part of a larger strategic port structure (Fig. 1), is actually one of the main symbols of the municipality of Herakleion (Spanakis, 1964, pp. 226–27; Tzompanaki, 1996, pp. 282–88, 463–71).

In a perspective representation of the Venetian Candia (modern Herakleion) from 1651 (Fig. 2), the port (circled in orange), facing the northern coast of Crete, is much smaller than the modern one. The fortress was part of the fortification of the city and controlled the entrance to its main commercial harbor.

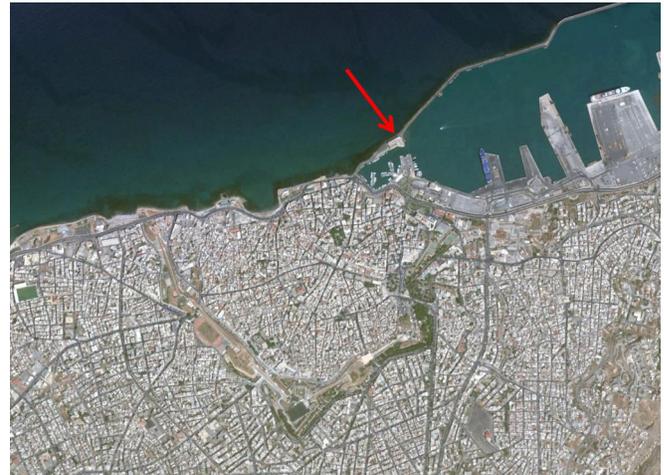


Figure 1: The city of Herakleion (Crete, Greece) and the Venetian Castle (red arrow) inside the modern harbor.

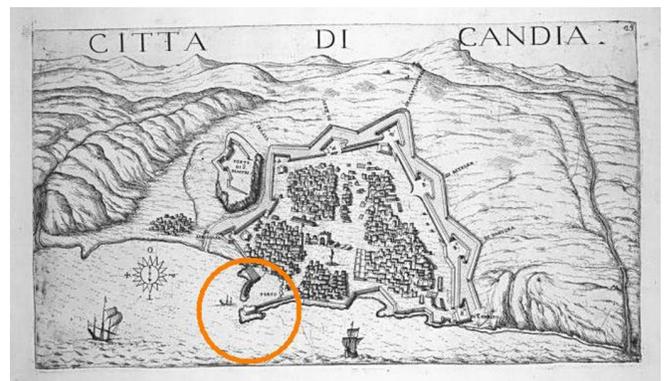


Figure 2: Artistic representation of Herakleion (former "Citta' di Candia" or "City of Candia") by Boschini (Boschini, 1651, p. 41).

According to Xanthoudides, ancient Herakleion was first created as Knossos' seaport, thus the first constructions in the area should have taken place during the Bronze Age (Xanthoudides, 1964, p. 43). He proposes that the large stone-block foundations and the ground of the two breakwaters of the port belong to construction during those early periods. Some Proto-geometric pottery was found in the wider area around the port during excavation that took place at the basilica of St. Peter at Bedenaki and the ancient writer Strabo mentions Herakleion as the seaport of Knossos during the Roman era ("And Cnossus has Heracleium as its seaport," Strabo, Geography X, 476–7; Spanakis, 1990, p. 12).

Based on recent archaeological excavation and research by the Ephorate of Antiquities of Herakleion, there is strong evidence



Figure 3: Top view of the Venetian Castle with red arrow pointing at the minaret (former lighthouse) on the upper roof and Northern edge of the building.

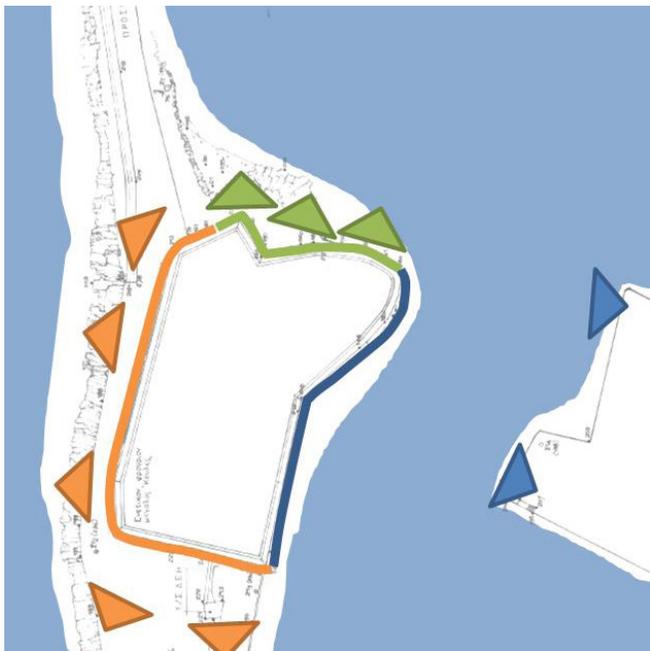


Figure 4: Plan view of the Castle with a representation of the phases (green, orange, blue in addition to the aerial view) of photogrammetric scanning.

to suggest that the port of Herakleion was already important and strongly fortified during the Hellenistic period (Sithiakáki et al., 2013; Muller, 2010). This fortification was rebuilt by the end of the Early Byzantine period (seventh or eighth centuries C.E.). During Arab rule (824–961 C.E.), the port had a significant role as a center from which goods and manpower were transported to the East. Its importance grew during the second Byzantine period, reaching a period of particular importance in Venetian times (16th to 17th centuries). Indeed, Venetians declared the port as one of the main naval stations serving their fleet in the eastern Mediterranean basin (and they adjusted the built structures to reflect this gained importance).

The *Rocca a Mare* probably succeeded a quadrilateral tower originally erected during the Hellenistic period, restored in

Early Byzantine times and then remodeled (and named as *Castellum Communis*) in the first Venetian period (13th or 14th century). The Venetian “Castello” acquired its final form over the period of 1523–1540, in replacement of an older fortress destroyed by earthquakes. The fortress dominating the entrance to the Venetian harbor has been variously referred to as the *Castello del Molo*, the *Rocca a Mare* and the *Koules* (the Greek form of its Turkish name *Su kulesi* or sea fortress, which bears out the significance of the area in terms of defense). We know that Venetians used raw material from the small island of Dia and from Fraskia to rebuild and reinforce the continuous destructions of the fort caused by strong winter sea waves (Manolióúdis, 2013; Spanákis, 1990, p. 32; Xanthoudides, 1964, p. 44).

Under Ottoman rule (1669–1898), a number of mainly defensive alterations involved the upper floor of the building, including the addition of crenellations and cannon emplacements. Further, a small mosque was added with the building of a minaret that replaced a Venetian lighthouse in the northeastern corner of the superstructure (Fig. 3).

The force of the sea was such that walls and foundations of the port and the castle were in constant need of repair. Even today, major operations of reconstruction and structural consolidation are ongoing, under the supervision of the Ephorate of Antiquities of Herakleion. The current project, funded by the Operational Program “Competitiveness and Entrepreneurship” of the NSRF 2007–2013, and consisting in surface and sculpture conservation and masonry reinforcement, is in its conclusive phase.

Ground Photogrammetry Fieldwork

The *Koules* is a monumental, two-story tall building around 14 meters, with a total surface area of 3,600 square meters. It sits on an artificial peninsula slightly larger than the building (along the northwest-southeast axes) which stands between the open sea on the northwestern side and the calm water of the internal port on the southeastern part.

The main goal of the project was to complete 3D documentation of the exterior of the building, allowing a deeper understanding of its construction (on a stone-by-stone scale) and structural soundness. Time constraints and the architectural design of the sea-fortress required proper planning of the photogrammetric fieldwork in order to optimize the forthcoming image processing.

For this reason, the photogrammetric scanning was divided into four phases (Fig. 4), consisting of a series of camera stations (in order) along the northern, western, southern, and eastern part of the fortress (this part was photographed from the other side of the inner harbor entrance) and finally a top view with the use of a remotely piloted aerial system (RPAS).

The fortress could be photographed only from very close distances (orange and green stations on Fig. 4), apart from the eastern side, which could be photographed by the other side of the small port entrance. Short distance photographs are usually quite problematic, and this difficulty becomes even more evident during photogrammetric processing.

The entire fieldwork was organized in blocks, so that each one of them had around 50 to 70 measured targets (around 260 in total, with an inter-distance of about 1 to 3 meters). For accuracy purposes, each target was measured with the use of a theodolite. As tie-points between blocks, six to eight of the targets were kept in place and measured (when possible) from two theodolite stations; this method also allowed for a quick checking of the accuracy of the general alignment.

Only the southeastern side (blue line on Fig. 4) could not be surveyed with a total station, so its alignment with the rest of the building was achieved through photogrammetric image matching of overlapping areas and temporary (non-measured) reference points.

Once the targets had been attached to the wall surface, the theodolite was used to measure each of them in a relative coordinate system and orientation. Afterwards, specific measurements on the tarmac and wall surface (where possible) had been taken also with a DGPS so that the model could be properly oriented and geographically positioned.

The operation was repeated on each side of the building, with the exception of the southeastern side, the most inaccessible from the ground. The eastern side also served as a clear comparative example of the easiness of approach in a different context. Given the larger distance from the building and the ability to photograph it from few well-angled stations, it allowed a much more fluid and fast processing with less image processing and masking involved.

Further, in order to have a complete and “watertight” 3D model surface, the top of the building was photogrammetrically scanned both with photographs from the rooftop and with photographs from low altitude with a RPAS (drone).

A number of obstacles had to be overcome for the completion of the task, the most important of which are described below. Main challenges were:

- Sun light and time constraints
- Intense air traffic above the *Koules*
- Wind/waves issues
- Fences and narrow areas with limited field of view
- Scaffolding

Sun Light and Time Constraints

The position and shape of the fortress, in combination with the strict time frame during which the photographs could be captured, constitute some of the most problematic aspects of the photogrammetric documentation.

Indeed, the limited space around the *Koules* was disadvantageous for specific stations for photogrammetry since they could hardly avoid direct sunlight and consequent glares in photographs of the crenellation. This fact, besides altering the chromatic response of surfaces in the digital camera, also produced noise and false image matching in photogrammetric processing.

The southeastern side of the building was much easier to document in this sense given the ability to photograph from

the other side of the small port entrance (in blue in Fig. 4) from a horizontal distance of about 60 to 80 meters.

Intense Air Traffic Above The *Koules*

For the requirements of the project, it was sufficient to fly between an altitude of 20 to 30 meters above sea level for a complete photogrammetric coverage, in respect of all civil aviation regulations, considering that the airport is 2 km away and the fort itself is used as reference point by pilots on take-off. Nevertheless, air traffic was not a secondary problem. Indeed because of the long tourist season on the island, many airplanes transit above the fortress during the day. No matter the altitude of airplanes, the areas around airports are generally restricted, especially during airplane transit/operations. Greece has no official regulations for RPAS so far; nevertheless, common sense precautions had to be taken into account. This made it hard to find a time gap when the drone could be safely used, especially when tourists were not around the fortress, in order to reduce risks such as bodily injuries.

Wind and Waves Issues

One of the reasons why this project is so vital is that strong waves from the northwest can easily damage the building's facade, contributing to the deterioration of wall surfaces and endangering the monument's life. In fact, the location of the fortress is one of the windiest spots on the island with strong winds that persist throughout the year. These strong winds also proved problematic to the documentation of the building during the ground fieldwork as well as causing difficulties with the stabilization of the drone in the air.

Fences and Narrow Places with Limited Field of View

Photogrammetric processing depends mostly on the camera, lens, and angle of view. Photographic cameras determine the file size and format, the quality of the image and the clarity of the result; together with the lens, camera construction determines the principal point (i.e., the optical or geometric center of the photograph) which is important for the photogrammetric processing. Generally, wide-angle non-zoom lens (called prime lens) are preferred in order to minimize image distortion during processing. An important aspect of photogrammetry deals with the angle of view. Homologous points and objects that appear only on photographs with very low angles (for example two photographs taken very close to each other) have much lower accuracy than objects on photos that are closer to 90 degrees apart.

The presence of semi-permanent enclosing fences (for the current and ongoing restoration) at close distance from wall surfaces (about 1.5 to 2 meters) considerably limited operability around the building, making it very hard to shoot detailed overlapping photographs with good angles and without obstacles. The frontal view of the facade was practically impossible to reach and consequently the orthographic view of that wall could only be interpolated from high-oblique perspectives (angles wider than 90 degrees), especially on the northwestern side.

The ideal solution in such a case would have been a more extensive use of low-oblique photographs from the unmanned vehicle, but this was not possible.

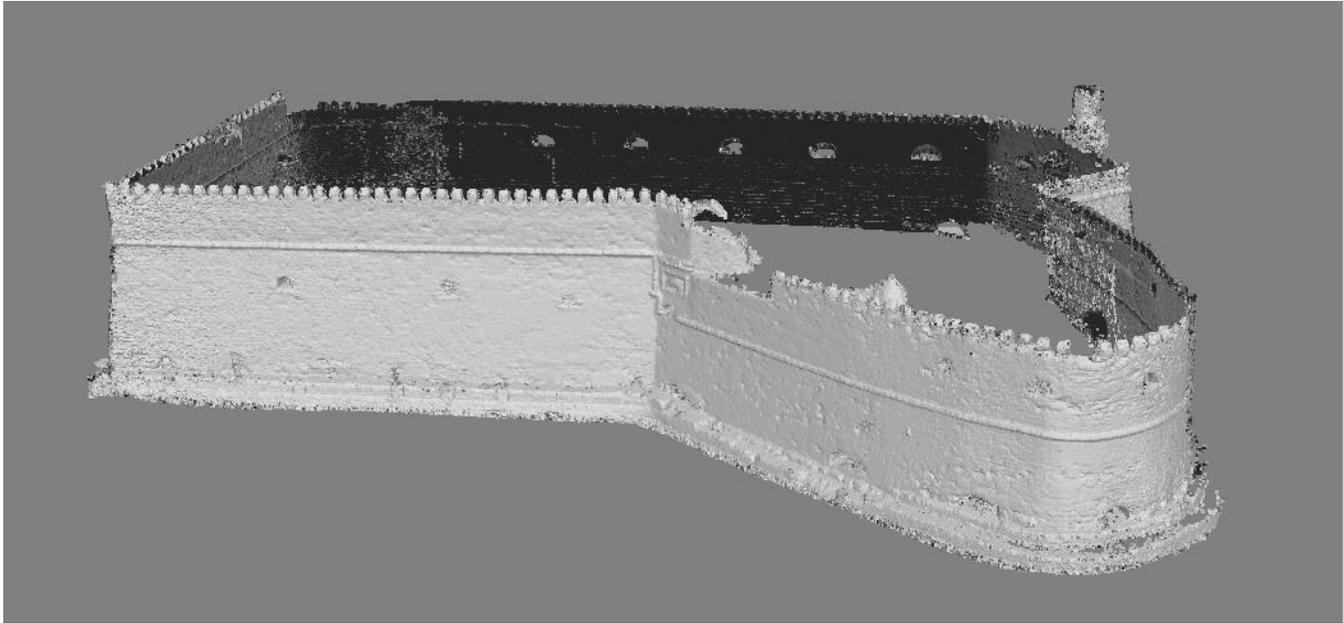


Figure 5: Perspective view of the dense point-cloud (70 million points) that constitute the sides of the building in the digital model.

Scaffolding

The restoration of the building facade was undertaken in steps, and each different day of photogrammetric fieldwork one area was covered by scaffolding for cleaning and another was just completed and exposed. The masking function of certain photogrammetric software allowed merging of data from different days, joining together partially covered areas with already cleaned and restored ones.

Results

The processing of about 3,500 photographs with 260 targets allowed the complete reconstruction of the Venetian fortress in 1:1 scale, properly oriented according to the Greek national coordinate system. The sides of the digital model (Fig. 5), comprised of 70 million points and 67 million faces (after surface cleaning), have been textured in a seamless view (with minor chromatic differences, normally limited to specific side).

The great advantage of the photogrammetric processing consists in the high scalability of the output. Indeed, once the photographs have been masked (if needed), aligned and oriented in space, the model is ready for further processing, so that, for example, specific areas of the building may be rendered with high level of details (dense cloud) or just as a simplified surface. For instance, one may want to undertake a deep study on the stone-block granulometry which would require a very high density of points; on the other hand, a lower resolution (and so a simplified model) for the building may be required for web dissemination or quick visualization. Both outputs can be achieved with the same preliminary alignment and orientation of cameras in any photogrammetric software package. For this reason, the above figure of points and faces is subject to change with the modification of parameters in accordance to the required final output.

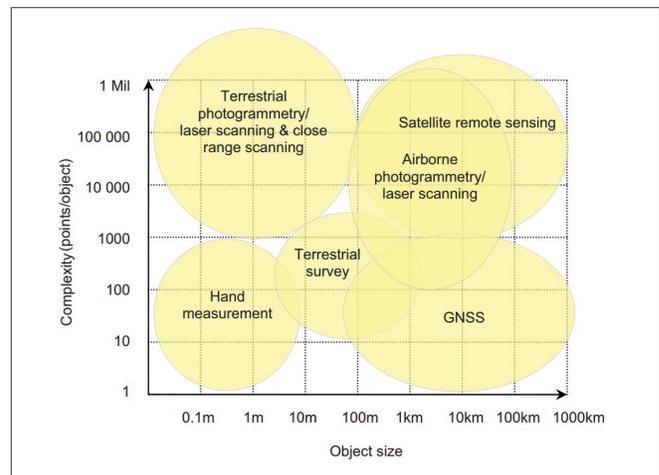


Figure 6: Three-dimensional survey techniques characterized by scale and object size (derived from Böhler presentation CIPA symposium 2001, Potsdam) (English Heritage, 2011, fig. 1).

Comparison with Other Methods

Architectural drawings of the fortress are of great value since they can be used for general measurements, volumes and perspective. Their rendering passes through symbolic levels made of codes and standards (Evans, 2000). The accurate measurement of surfaces on the contrary provides a clear and objective documentation of the state of preservation of the building allowing one to identify any structural issues or potential stability problems or assess the general condition of the site (Barber et al., 2006).

The only alternative method available for a structure of this type and size (Fig. 6) is with the use of laser scanners (Haddad, 2011). Terrestrial laser scanners (TLS) normally provide a predefined level of resolution that can be improved only by

moving closer to the subject of scanning; TLS normally produce non-uniform point cloud density with high point density related to proximity to the scanner itself. On the contrary, the possibility to generate more or less dense point-cloud anytime and at specific parts of an object, as photogrammetry can do, has no competition. Certainly, the photogrammetric output has limitations, which are normally related to the camera resolution. Nevertheless, recent developments in this area are demonstrating great margins of improvements even with low resolution or printed photographs.

Another important aspect in the comparison between laser scanning and photogrammetry is the logistics of fieldwork. It is normally necessary for laser scanning to set up more stations to interpolate the final point-cloud. Photogrammetry, on the other side, is based on actual photographs which can be compared to a certain extent to single stations of a TLS (although a single image without overlapping with the others cannot produce photogrammetric 3D points).

One of the main differences between the two systems is the time required for fieldwork and data processing. Normally, laser scanners require longer time in data acquiring but produce 1:1 scaled measurements (the latest models also produce georeferenced point-clouds); photogrammetry can be faster in image collection but takes longer time for point-cloud generation and scaling or geo-referencing.

Finally, photogrammetric software can nowadays work even with photographs taken for other purposes. The case of the monumental carved Buddha statues of Bamiyan serves as a good example. These sixth-century monuments in Afghanistan were destroyed by the Taliban in 2001. A digital model of them could be attempted with random tourists' photographs collected from the web predating the statues' complete destruction (Gruen et al., 2003).

Digital Model as Research Tool

The existence of a digital 3D model of a building allows one to perform several tasks that would be difficult to conduct on site. One of them is the analysis of surfaces and the localization of potential structural issues on the building. The digital model allows rotating and visualizing the building's architecture from artificially created positions (i.e. not only from the ground-up, as most visitors experience the visit to the building).

With few inputs in specific software (such as CloudCompare or Meshlab), one can easily extract cross sections or projective views. Specific algorithms may also help highlighting specific issues, such as the artificial shadow casting over the untextured surface. Further, specific functions of point-cloud visualization and editing software may be used to manually draw features on the surface, similar to a 3D blackboard or virtual graffiti (Fig. 7). This system allows, for example, an immediate

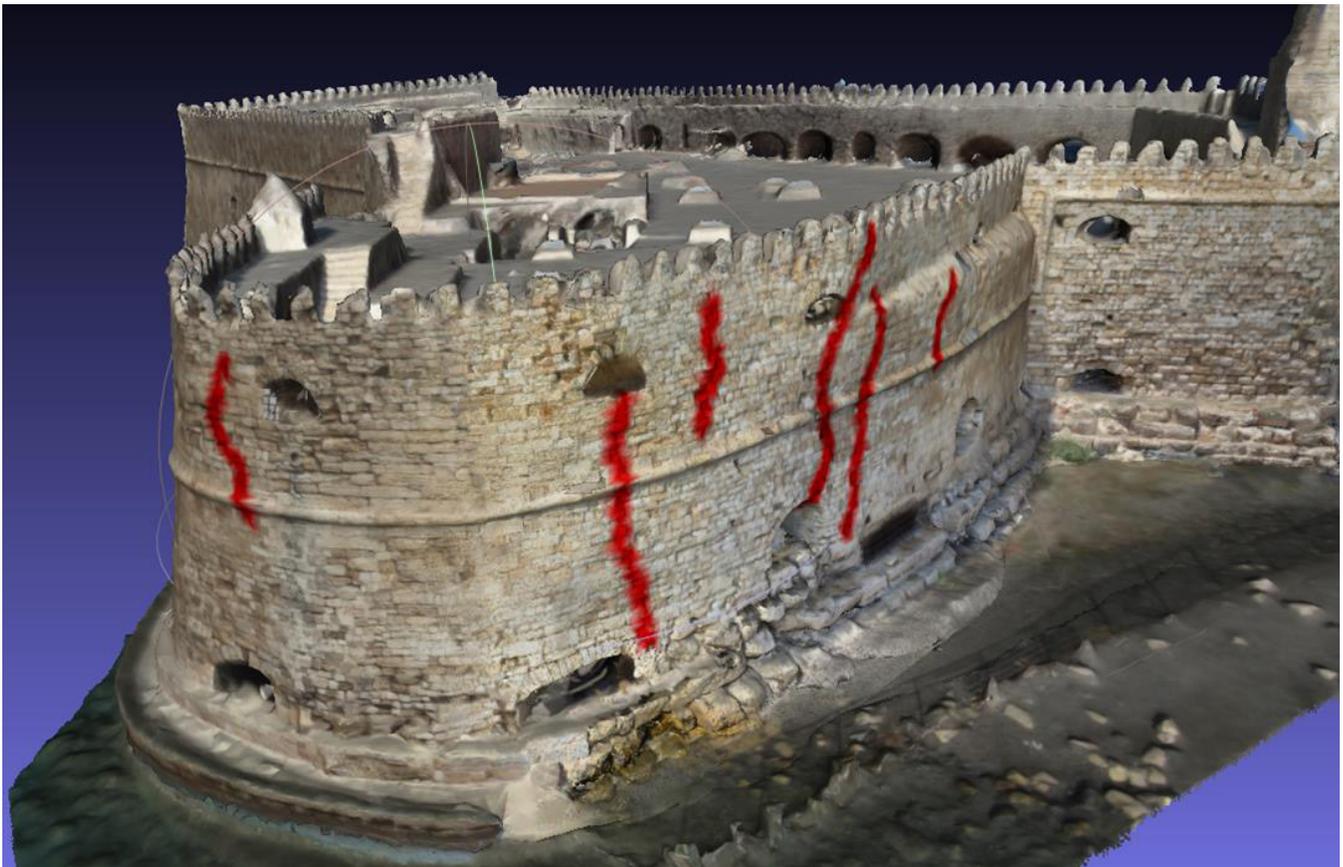


Figure 7: Northeastern bastion of the Venetian fortress from the north. In red, structural issues from visual computer-aided analysis.

visualization of structural issues, and facilitates the mapping of their distribution on the exterior surface of the walls.

In the example of Fig. 7, the structural integrity of the building seems particularly threatened on the northeastern bastion, where cracks can be easily traced, highlighted and visualized over the 3D photogrammetric surface.

Another added value of photogrammetry for the preservation of cultural heritage lies in the possibility to integrate and process old photographs into a model generated from more recent photographs. Although the print resolution of published images from the early 20th century is not optimal for accurate processing, their use in archaeology can still provide important information. An example of such an application is the use of photographs from the early 1900s of the fortress into the photogrammetric model.

In 1900, the Italian architect, Giuseppe Gerola, was sent to Crete by the “Venice Art and Culture Scientific Institute” to study, photograph and record all Venetian monuments in Crete “before time passage consumed them.” Part of those photographs have been published and some prints depict the *Koules* at that time (Gerola, 1905). By adding them to the photogrammetric processing, one can see for instance the exact location from which the photograph was taken. Indeed, with the use of common points between rendered 3D model and pixel on the specific (scanned) photographs, photogrammetric software can reconstruct the pose (camera orientation) and calibration (interior camera parameters), and thereafter the coordinates of the camera with respect to the model. By applying this calculation and by projecting the point of photo-shooting into a geo-referenced orthophoto for instance, one realizes that the photograph had been taken from one of the structures of the old port which is not present anymore. Additionally, the same old photographs can be overlaid with great accuracy on the new model to highlight differences in visual comparative analysis (Fig. 8).

Beside the archaeological and documentation value, the 3D model has great potential for the dissemination of cultural heritage buildings to the public (Haddad and Akasheh, 2005). A tablet application (Fig. 9) has been created at the GeoSat ReSeArch Lab for experimental purposes to identify possible ways of community involvement. The tablet app recognizes the given image of the fortress (in this case a Google-provided satellite image) and allows the user to visualize the 3D model from any possible perspective just by moving the tablet around. Images of the fortress could be easily printed and displayed on an information board close to the monument (or in other places of the city) with a link to download the application (for example via QRcode). Furthermore, the 3D model can be made more attractive with respect to public involvement, with reconstructed missing part (such as the Ottoman minaret in place of the 19th-century lighthouse) or animated with avatars of people with historical dresses moving around or on the roof of the monument.

Further Developments

Continuous monitoring of the fortress’ walls will be beneficial as support for the localization of possible changes on the shape and the surface of the building during a long period of



Figure 8: Detail of the *Koules* after the photogrammetric processing with photographs from 2013–2014 (top) and 1900 by G. Gerola (Gerola, 1905)



Figure 9: Experimental tablet application (developed by L. Argyriou and N. Papadopoulos at the GeoSat ReSeArch Lab) for 3D model visualization and community involvement. Rotating the tablet around the object will provide different perspective of the fortress in an intuitive way.

time. Taking advantage of the 3D model already available and presented here and the knowledge gained through this project, new versions of the *Koules* could be easily created to highlight and track any changes from previous 3D models of the fortress and help predict potential structural issues in the future.

Further, some approximate measures of the interior spaces of the building could be calculated to estimate volumes of stones or wall thickness so that the general stability and static assessment of the building can be evaluated with more accuracy. Obviously, precise scanning of the interior spaces would provide further valuable information. The 26 rooms

of the fortress could be perhaps scanned with fast and low-priced technological solutions such as modified Microsoft Kinect devices. Such devices, giving the possibility to scan and produce in real-time a 3D model in 1:1 scale with the principle of “structured light,” are particularly suitable for interior spaces since the infrared laser they use is too weak to be captured with sun illuminated surfaces.

The combination of the 3D models of the exterior (already available) and interior of the building will also assist researchers in wall surface analysis and volumetric measures. From the reconstruction of the exact volume and shape of stone blocks of the building, one could try to discriminate the used quarry from a given set of quarries for the same material or try to reconstruct the infrastructure needed for the transportation of the building blocks.

Conclusions

The recent photogrammetric reconstruction of the exterior of the Venetian fortress in Herakleion (Crete, Greece), highlighted the successive repairs and additions carried out on the building throughout the centuries.

A number of issues have been encountered during the photogrammetric scanning of this monument and are presented here. Nevertheless, the case study demonstrated how photogrammetry may be an efficient and cost-effective way of documenting complex monuments. Most of the time required to complete the task is limited to the image-processing, and this can take place elsewhere, not necessarily in the field (especially beneficial in crowded tourist destinations). Also, different levels of detail can be extracted according to specific output or computer processing capabilities.

The affordability of such a proposed method and the possibility to reuse the obtained results in several projects makes the 3D model a particularly interesting educational tool. Surely, new problems are arising, such as the storage requirements, the dissemination of such large amount of data, and the publication of digital models. Nevertheless, the possibility to extend the documentation of historical and archaeological artifacts to three dimensions (moving forward from the traditional documentation done with 2D drawings) constitutes an important contribution to the understanding and preservation of cultural heritage.

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