Visualizing Culture: What Can Go Wrong Behind the Scenes? Terrestrial Laser Scanning of an Early Christian Basilica on the Island of Kalymnos

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Abstract

Terrestrial laser scanning is one of the most advanced technological methods currently employed in creating three-dimensional models of artifacts, buildings and sites. Data acquisition and analysis is used for study and archival purposes and for reconstruction projects associated with the preservation, conservation, and protection of cultural heritage, whilst researchers and the general public are able to access the material from around the globe. This digital database can also be used to create 3D visualization theories when combined with cultural elements sourced from archaeological, textual, historical and ethnographic data. The end result allows a better understanding of society and culture. However, most are unaware of the technical problems associated with such projects as they are only presented with the end product: the final model. The data collecting and analyses processes can be time consuming and fraught with technological challenges. In an effort to create a digital archival record of the early Christian basilica of Christ of Jerusalem dating to the 5th–6th centuries on the Greek island of Kalymnos, we present highlights of what goes on "behind the scenes" during data acquisition and analysis. In addition to the technological challenges, the scope of this project is to employ a virtual approach to the study of the monument by incorporating cultural elements to create a 3D extended reconstruction of the site. Such a model will enhance our knowledge concerning the various activities that contributed to the island's wealth and the involvement of the Church in the economic life of the island.

Introduction

The application of Terrestrial Laser Scanning (TLS) to the study of monuments and sites that have been investigated using traditional empirical methods affords a unique opportunity for a reinvestigation through a collaborative interdisciplinary approach.[1] The 5th century early Christian Basilica of Christ of Jerusalem on the Greek island of Kalymnos was selected for this study as it is one of the best-preserved and well-documented monuments of this period, in an area that was once the political and religious centre of the island (fig. 1).[2] TLS was chosen as an exploratory tool because it is a non-invasive and highly accurate surveying method. The instrument used, a Trimble TX5, scans and generates a dense "point cloud," a colour image which is made up of billions of points

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Fig. 1: Remains of the early Christian Basilica of Christ of Jerusalem on Kalymnos.

and is viewed in 3D, unlike a digital photograph which produces only colour information in 2D. The raw data collected is processed using SCENE, a software package, to create a reality-based 3D digital model, from which measurements are used to produce topographical maps, plans, cross-sections, elevations, line drawings, and ortho-images. The objective was to generate a 3D digital archival record of a vastly larger and more accurate volume of measurements of the basilica for documentation, conservation, preservation, restoration and interactive visualization purposes.[3] Thus Scholars and professionals from around the globe can access this digital record for research and educational purposes.[4]

For this paper, the intent was to create an extended reconstruction of a digital 3D model of the basilica and associated subsidiary structures by introducing cultural elements obtained from archaeological, textual, and ethnographic data.[5] This would allow for the display of various activities that took place at the site and contributed to its economic development and that of the island, in general, during Late Antiquity.

The scanning process however was challenging as numerous technological problems were encountered while collecting and analysing the data: mechanical failure, software glitches, and loss of raw and processed data.[6] As a result of these drawbacks, recommendations are made for the manufacture of more robust equipment for use at remote and isolated archaeological sites and guidelines for easy access to technical support through one telephone number valid world-wide. An introduction to the site and the laser scanning procedure are presented below followed by a proposal for an extended reconstruction of a 3D model of the site that includes cultural elements for research and educational purposes.

Case Study: The 5th Century Basilica of Christ of Jerusalem on Kalymnos (fig. 1)

The basilica of Christ of Jerusalem was selected for study, as it is the best-preserved early Christian basilicas on the island, that lies within the ancient sanctuary of Apollo Dalion. This site was once the political and religious centre of the island and appears to have maintained its significance into Late Antiquity (4th to the 7th centuries), for it became an important Christian centre on the island. The basilica was investigated in 1854–55 by the British archaeologist Charles Newton, and in 1937 by the Italian epigraphist Mario Segre.[7] In fact, both the basilica and its mosaic pavements have been the subject of numerous studies over the last 152 years,[8] however, the first systematic excavations did not begin until the 21st century by the Greek archaeologist of Kalymnos, Mixalis Koutellas, under the auspices of the Ephorate of the Dodekanessa. In all three instances (Newton, Segre, and Koutellas) the monument was investigated using traditional (manual) empirical methods of excavation and documentation.[9] Excavations by Koutellas focused on the basilica and associated subsidiary structures and service areas, and exploration of the surrounding area comprising approximately 10,000 sqm (fig. 2).[10]

Fig. 2: Highlighted Google Earth map of the archaeological remains of the pilgrimage site with the basilica of Christ of Jerusalem.

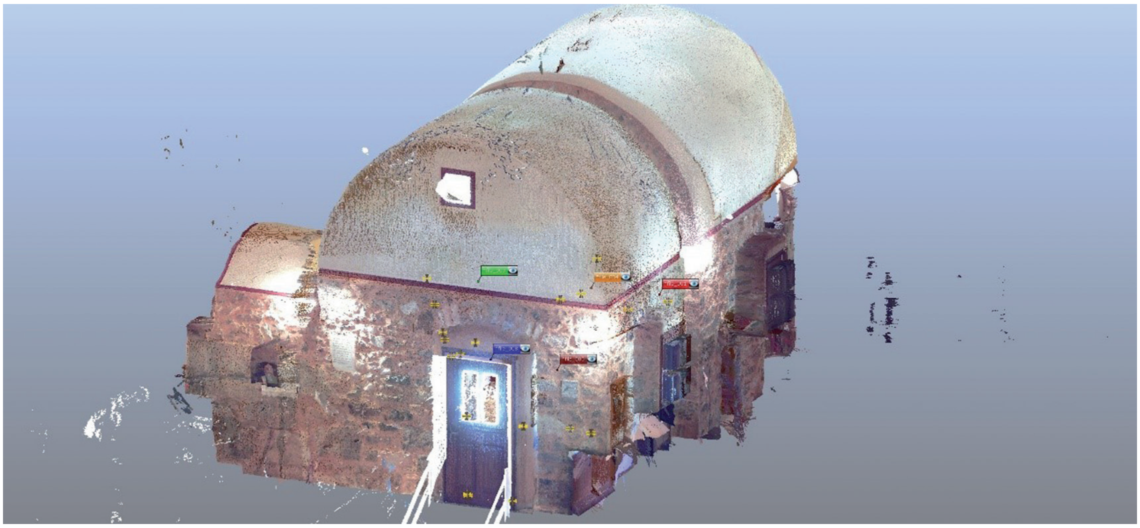

Fig. 3: Point cloud (incomplete) of the exterior view of the Chapel of Ypakoue.

The site was transformed into an archaeological park and features the early Christian basilica complex that includes: a baptistery, cooking facilities, a possible burial area and service areas, a triconch basilica of Saint Sophia to the east, an ancient roadway to the west, and a series of chambers and remains of a lime pit to the south, an area for industrial activity associated with the construction of the early Christian structures.[11] According to Newton's account, numerous other apsidal and rectangular structures were erected in this area, which he thoroughly destroyed as "the labor of this work of demolition was very considerable."[12]

The TLS project focused on scanning the basilica and ancillary buildings connected to the structure. Thus, the small church of Panaghia Ypakoui at the south-east corner of the basilica, constructed in 1902 and currently in use, was also scanned. It replaced a previous existing small chapel built in the Byzantine period. The chapel was constructed from spolia originating from the basilica and was included in the project for archival purposes.[13] The resulting high resolution digital data bank collected will be used for displaying and presenting spatial relationships of the chapel in a 3D surface model for preservation and conservation purposes (fig. 3).

Fieldwork

A quantitative approach was used to conduct the study, by applying TLS and appropriate software to collect and process data. A Trimble TX5 was chosen, a non-invasive small and portable surveying, laser-based instrument that sends out millions of laser pulses while slowly rotating in a 360 degrees horizontal circle and +/− 90 degrees vertically. Each pulse strikes an object and is reflected back to the scanner, which determines the 3D coordinates (x, y, z) of every point to an accuracy of a few millimetres. The returned pulses create a grid, with the grid size varying from sub-millimetre to a few centimetres. Special software (SCENE) is used to generate a dense "point cloud" that is a colour image, which is made up of billions of points and is viewed in 3D, unlike a digital photograph which produces only colour information in 2D. From a distance, the point cloud looks almost photorealistic, while close-up it resembles just a series of dots.[14]

The basilica was scanned in sections and spheres were setup as a boundary marker for stitching the images (a process called registration) in order to produce a coloured point cloud image of the site using SCENE software and Trimble RealWorks v7.2 software. A Global Positioning System (GPS) receiver was also used to enable the point cloud to be tied to the national geodetic coordinate system of Greece (ΕΓΣΑ87).

During the first day (day 1) in the field, the interior of the chapel of Ypakoui was scanned; eight scans were required to complete data acquisition. However technical problems were encountered and it was therefore necessary to rescan the interior. Data analysis and processing of the point cloud of the interior was completed with difficulties (fig. 4), but the point cloud view of the exterior was not completed as the red roof is missing (fig. 3). Not all set ups of the exterior scans of the chapel and the aerial and angle views of the basilica have been processed (figs. 5, 6).

Technical problems and major hardware issues were encountered near the end of day 1, while scanning the exterior of the basilica. The bright sunlight for example made it difficult to view the scanner screen so a temporary covering (in this case a plastic bag) was required to cover the instrument. Additional problems were met while scanning the mosaic pavements and the east side of the basilica during the morning and midday, as some sections of the apse were in the shade, whereas others were too bright or not visible at all. Scanning of the mosaics required direct sunlight from above in order to avoid shadows and the apse was rescanned in the late afternoon when the entire east side of the basilica was in the shade.

Fig. 4: Point cloud, interior view of the Chapel of Ypakoue.

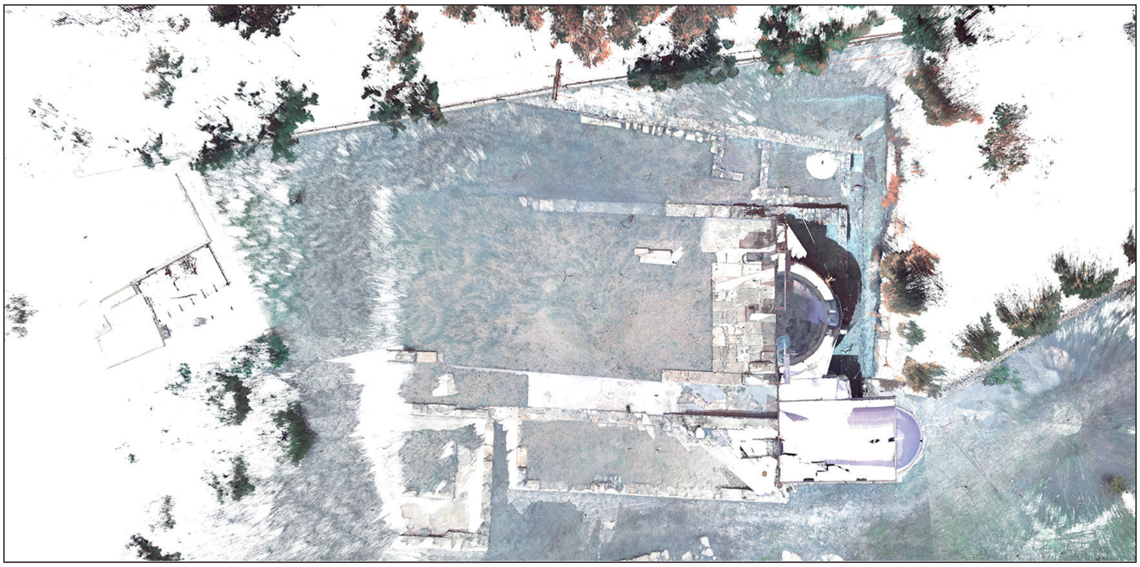

Fig. 5: Point cloud (incomplete) of the basilica of Christ of Jerusalem, top view.

Another mechanical problem occurred after the first setting was scanned and processed successfully. The scanning results from the second scan were inadequate and the third setting was unsuccessful as the scanner ceased to function and the message "scanner operation failure" appeared on the screen. A series of SOS messages were sent to Trimble dealers in Greece, Canada, and US for assistance. Additional problems were encountered while installing the new program, as the message "error while installing new firmware program" appeared on the screen, and many hours and sleepless nights were spent testing the software and processing the raw data to confirm that the program worked. In the end though, the scanning project was completed, taking of course much longer than what had been anticipated.[15] In sum, problems of this nature can in most instances be readily resolved if appropriate guidelines for easy access to technical support were available, such as a telephone number valid world-wide with 24-hour technical support.

In total, 79 setups were required to scan the monument and six billion points were amassed within eight days. During the first six days, 69 medium resolution quick scans, of 15 minutes each, were conducted, and on days 7 and 8 a series of ten one-hour, high resolution scans. Rescanning at a higher resolution reveals details of smaller features that may have been missed (such as mason marks) and produces clearer images of the letters found on the inscribed blocks used to construct the basilica.

Since TLS collects an enormous amount of data, which far outstrips that which is collected by traditional surveying or photogrammetric techniques, this volume of data is difficult to manage and most computers are unable to store and process it at the same. A Dell Alienware laptop was purchased in 2016 for the project, but it too could not store and process the raw data concurrently. In fact, a malfunction of the laptop resulted in

Fig. 6: Point cloud (incomplete) of the basilica of Christ of Jerusalem and the Chapel of Ypakoue.

the loss of all data processed at the site, including aerial photographs and video taken with the drone, only the raw data was saved.[16]

OUTCOMES: Proposed 3D Visualization

Once processed, TLS data assists in preparing visualization theories, scientific models and an extended reconstruction of the basilica for study and display purposes, similar to the models produced for the site of Uruk. Technical models of urban structures from Uruk were created by adding texture, realistic lighting, and scientific details from excavation data, satellite imagery and geo-archaeological surveys. A multidisciplinary approach was used to contextualize these models (by adding cultural elements utilizing archaeological, textual, and ethnographic data) and create an extended reconstruction depicting a specific religious ceremony of the Sumerian New Year in the 21st century BC. The intent was to reconstruct an ancient society and bring to life not just the architectural and landscape elements of a cityscape, but to demonstrate "how space was occupied and utilized, and present 'a glimpse of everyday life'".[17]

The basilica of Christ of Jerusalem on Kalymnos and its ancillary structures serve as an excellent case study for creating a similar, cultural visualization theory, but one which focuses on the day-to-day economic activities of a major pilgrimage centre in the 4th to 7th centuries. The material remains and the location of the site lend credence to the proposal that the early Christian basilica was part of a major Episcopal centre that featured: at least two church complexes of which one was a *Martyrium* (basilica of Saint Sophia), numerous service structures, possibly a bishop's residence, as well as housing for those involved with the function and maintenance of the site.[18] This hypothesis is further strengthened by the discovery of a 5th-century inscription that makes reference to an *economos,* a certain *Eygenios,* one who oversees the economic affairs of a bishopric.[19] The site is nestled at the crossroads of a main arterial east-west route and the mountain pass into the small fertile valley of Vathy to the west (fig. 7) and the prosperous early Christian town of Hellenika, a centre of trade and commerce, with its five basilicas.[20]

Such early Christian complexes became important religious and community centres, providing shelter and food for travellers, the poor and pilgrims, and also functioning

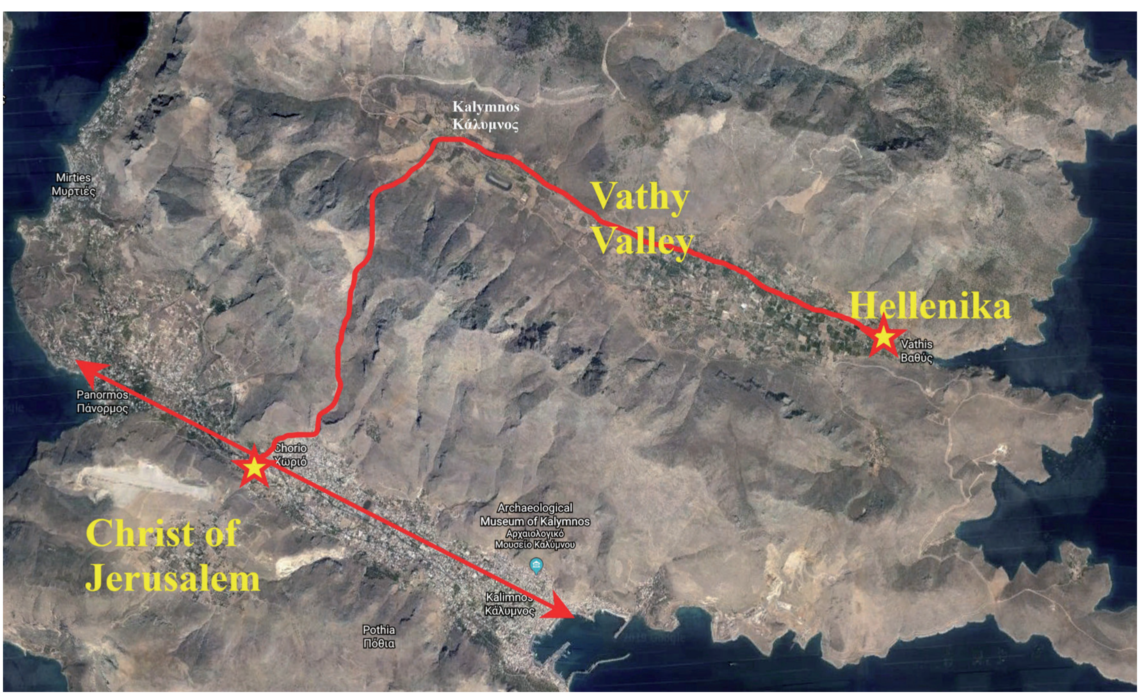

Fig. 7: Highlighted Google Earth map of sites: Christ of Jerusalem, Vathy Valley, Hellenika and associated basilicas.

as hospices and hospitals for the ill. To accommodate the public, a variety of facilities were constructed including lodges, baths, kitchens, and facilities for the storage of food and utensils, as well as for various economic pursuits such as wine and oil production, industrial activities and shops. Similar subsidiary structures adjoining major basilicas have been documented at other sites in Greece, and further afield in Jerusalem, Palestine, North Africa, Syria and in the rural settlements of Anatolia.[21]

One of the structural features of particular interest in the proposed visualization theory is the area Γ (17,35 × 4,35 m) attached to the south aisle of the basilica (fig. 8). It has been tentatively identified by the excavator as a possible *diakonikon* a space used for

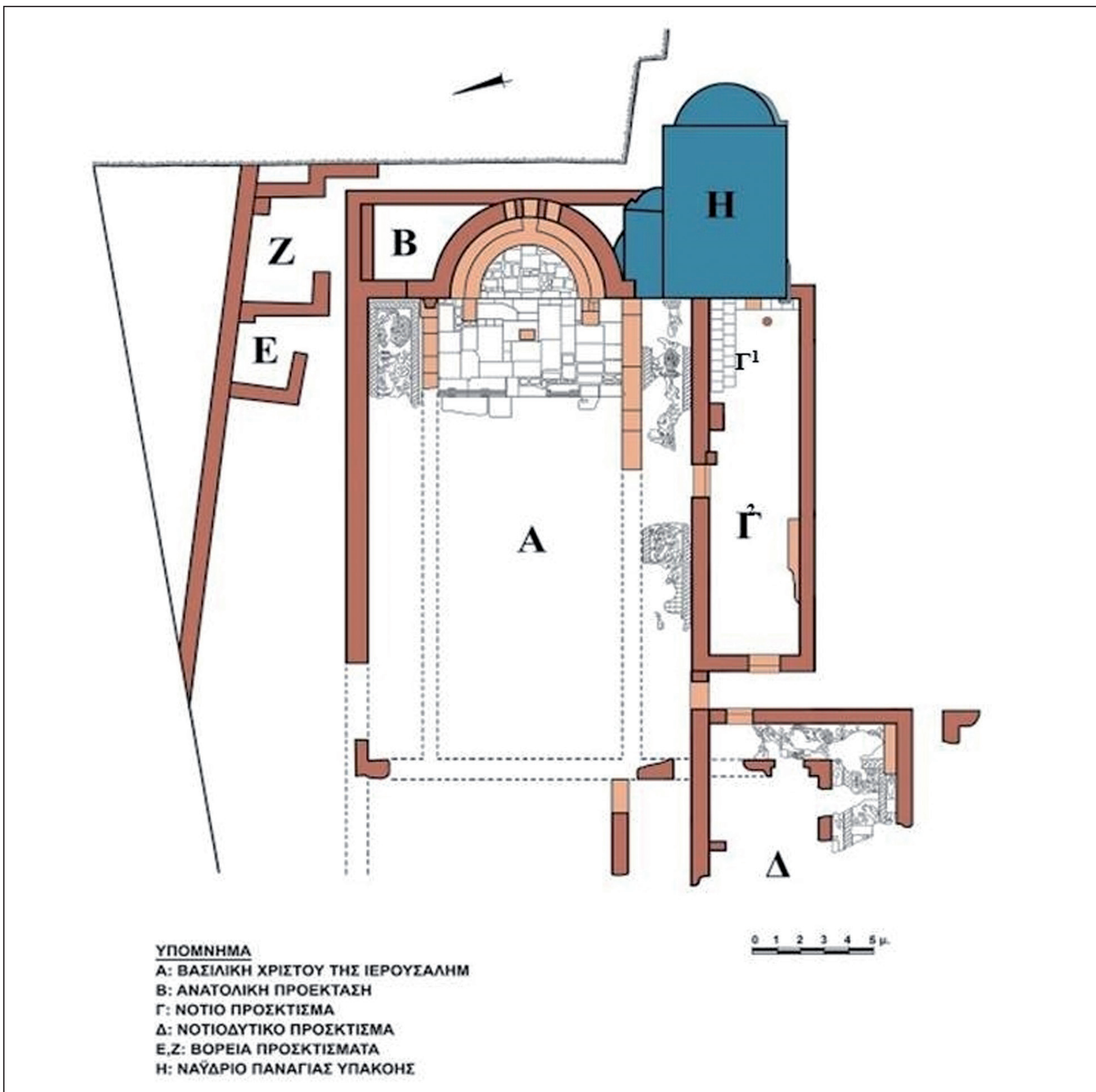

Fig. 8: Plan of early Christian basilica of Christ of Jerusalem, Kalymnos.

preparing the gifts for Liturgy and storage of associated implements based on literary accounts.[22] Alternatively, it may have functioned as a hospice, *xenodocheion,* a structure that also served as a shelter for travellers, pilgrims and envoys of bishops, and space for storing and preparing food.[23] No moveable artifacts however were found to support either theory. Therefore, in producing a 3D extended reconstruction of this space the architectural remains must be examined.

The structure was divided into two distinct areas defined by a narrow corridor: Γ^1 one to the east is defined by a terracotta tile floor and Γ^2 to the west.[24] In a domestic context, terracotta tile pavements were commonly associated with bathing areas, latrines, certain types of storage facilities, areas for food preparation, and in general for areas open to the sky.[25] Therefore this eastern part of the structure could have served as a service area for storage or preparation of food, an activity well documented in basilica complexes. Conversely the area to the west which featured a bench along the wall could have served as a rest area for pilgrims, a *xenodocheion,* but also used by the local community for various philanthropic pursuits of the church.[26] These different interpretations of the function of space Γ would ultimately influence its reconstruction. Would both spaces (Γ^1 and Γ^2) have shared the same roof, or would area Γ^1, defined by the terracotta floor tiles, have been roofless, reserved for the outdoor preparation of meals perhaps? If the area to the west, which featured a bench along its south wall, functioned as a *xenodocheion,* did it have a second story to accommodate pilgrims overnight?[27] We look forward to solving the answers to these and other questions, concerning the types of daily activities and the nature of the built environment, and to provide a glimpse into the economic life of an early Christian centre.

Conclusion

Despite the challenges associated with technological tools in documenting material remains, the end results are most promising. Digital data with the use of appropriate software packages can be used to create visualization projects (visualization theories, virtual reconstructions and interactive visualizations) for scholarly research, professional and educational purposes. When combined with cultural and historical knowledge they not only recreate the physical and built environments of a society but also display human activities, that is how space was utilized and populated. For the Early Christian Basilica of Christ of Jerusalem such a model will highlight the various economic pursuits and daily activities of this major pilgrimage centre and its contributions to the island's wealth and the involvement of the Church in the economic life of the island. Visualization projects therefore are but intermediary steps in the research process that facilitate in the interpretation of material remains and understanding of past cultures. They serve as a tool for addressing important research questions and hypotheses, concerning for example the formation of urban identities, urban development, or economic networks.

For professional and educational purposes an updated permanent digital archival record can be used to document changes in the stability and/or deterioration rate of a monument. In turn this would allow museum professionals and government agencies to take appropriate conservation and preservation measures, create education-awareness programs for the protection of cultural heritage, and enhance museum visitor experience for students and the public TLS therefore "is one of the most effective instruments in monitoring the remains of past human activities."[28]

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Notes

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[1] Pavlidis et al. 2007.

[2] Koutellas 2016.

[3] Tsingas et al. 2008; Scheiblauer et al. 2009; Haddad 2011; Núñez Andrés et al. 2012; Barber et al. 2014

[4] For deterioration of monuments, see Warscheid and Braams 2000; Dewey 1999.

[5] Uruk project, see Hageneuer 2014.

[6] No technical difficulties were encountered in 2016 while scanning the "Insula of Houses" at Abdera (Greece) an area of ca. 50 × 100 m that was scanned with 50 setups in three (10 hr) days.

[7] Newton 1883/1856; Serge 1938, 1944/45; Karabatsos 1994; Koutellas 2016, 47.

[8] Ragkavis 1854; Phlegel 1896; Reises 1913; Tarsouli 1948; Lazarides 1953; Pelekanidis 1974; Volanakis 1980; Assimakopoulou-Atzaka 1991; 2014, 45–46, 53; Koutellas 2006.

[9] Pavlidis et al. 2007.

[10] The project was funded by the local city council of Kalymnos and the Regional Economic Government Development Program of the Southern Aegean Islands 2000–2006, Koutellas 2009; 2016, 49.

[11] Koutellas 2006; 2016. The triconch basilica was probably a *martyrium.*

[12] Newton 1856, 27.

[13] Newton 1856, 25–27; Koutellas 2016.

[14] Tsingas et al. 2008; Barber et al. 2014; Chow 2014; Dare – Ahn 2014.

[15] Preliminary results of the Chapel of Ypakoue were presented at a poster session at the CHNT 21st Conference in Vienna, Nov. 2017.
[16] Dell laptop Alienware features: 1 TB 7200RPM; 32 Gb memory; Intel Core i7-6820HK; Quad-Core [4 CPUs], 8 MB Cache; Dynamically overclocked up to 4.1 GHz. Processing raw data to create orthophotos and fly-throughs is time consuming, and equipment malfunctions can occur that result in delays and the loss of many hours of work.
[17] Hageneuer 2014. Technical models are suitable for display in museum and exhibit areas.
[18] Possibly the various buildings destroyed by Newton 1856.
[19] ΕΠΙ ΕΥΓΕΝΙΟΥ ΟΙΚΟΝΟΜΟΥ ΕΤΕΛΙΩΘΗ ΤΟ ΕΡΓΟΝ, Koutellas 2016.
[20] Zisimou-Tryfonidi 2014, 178–196; Karabatsos 1994, 259–362; Koutellas 2003.
[21] At Paliambela, see Karavieri 2017; Halkidiki, Mesogai, and Lavriotiki, see Zisimou-Tryfonidi 2014; 2014; villa of Herodes Atticus at Eva Loukou, Papaioannou 2018, 350–351. 353–354.
[22] Identification based on location as mentioned in the *Testamentum Domini nostri Jesu Christi* and the "Apostolic Canons", see Koutellas 2016, 67.
[23] Some were simple rooms adjacent to a church, see Cilliers et al. 2002, 63; Zisimou-Tryfonidi 2014.
[24] The pavement in $Γ^2$ is destroyed, see Koutellas 2016, 66–69.
[25] Papaioannou 2003.
[26] Room with bench and domestic activities next to narthex of Knossos basilica, Zisimou-Tryphonidi 2014,100.
[27] The width of the walls (0.62 m) were sufficient to support a second storey, see Koutellas 2016.
[28] Haddad 2011, 117.

Image Credits

Fig. 1: M. Koutellas. – Fig. 2: Google Earth. – Fig. 3–6: by author. – Fig. 7: Google Earth. – Fig. 8 modified from Koutellas 2016, 77, eik. 6.

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