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Virtual Reconstruction of the Temple on the Acropolis of Kymissala in Rhodes

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Abstract: In recent years, the rapid development of technology has offered scientists new powerful tools. Especially in the field of cultural heritage documentation, modern digital media are an integral part, contributing significantly to the process of recording, managing, and displaying architectural monuments, archaeological sites, and art objects in a fast and accurate way. Digital technologies have made it possible to produce accurate digital copies of heritage sites and contribute to their salvation and conservation. At the top of the hill of Agios Fokas, acropolis of the ancient Demos of Kymissaleis, are the remains of a small Hellenistic temple of the 3rd–2nd century BC. This article proposes a virtual reconstruction of the temple on the acropolis of Kymissala. The geometric documentation of the temple and the creation of a three-dimensional model with its virtual reconstruction are analyzed. Modern photogrammetric methods are applied by taking digital images in the context of the experimental application of a relatively simple and semi-automatic method that does not require highly specialized knowledge and therefore can be used by non-specialists. With the use of modeling software, a three-dimensional model of the temple is created with the main goal of its virtual reconstruction.

Keywords: 3D modeling; virtual reconstruction; digital technologies; archaeological research

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1. Introduction

Archaeology as a science reflects the amazing diversity of human life around the world over the centuries. It aims to explore the past and the evolution of humanity and is considered as the main source of knowledge about ancient and extinct civilizations. To reconstruct history, archaeologists rely on all the evidence left by our ancestors, which can be as small as, e.g., tools and jewelry, or as large as architectural remains. Therefore, it is important to study, record, and display all archaeological information in a systematic way. Over the years, archaeologists have used traditional methods to bring to light the treasures of the past. In recent years, the use of new technologies has increased exponentially, affecting every aspect of our lives. Naturally, such technologies have also entered the field of archaeology, expanding and developing the traditional methods of two-dimensional mapping and the display of archaeological information. Drawings, graphs, and photos have been replaced by digital images and 3D restorations, offering a new dynamic in the science of archaeology. More specifically, virtual archaeology is a field with a wide application spectrum, which offers great tools for the study and visual interpretation of the past, which, on the one hand, enhance the archaeological process and on the other hand bring the public closer to the science of archaeology. The digital 3D representations of archeological sites and monuments allow for a novel presentation of ancient relics, whether they are building remains, or movable finds and traces of civilizations. Especially in cases where archaeological information can only be understood by experts, 3D graphics software and digital data visualization can provide enhanced representations. In this way, researchers, especially from other disciplines, can better understand the different phases of a site or a monument through photorealistic renderings thus enhancing research and helping scientifically sound conclusions.

In this paper, the use of contemporary ICT (Information and Communication Technologies) technologies is described to virtually reconstruct a temple whose remnants lie on the Acropolis hill in Kymissala, an important archaeological site on Rhodes, an island in the South Aegean Sea. The virtual reconstruction is based on the high-resolution 3D model of the ruins, which was constructed using image-based modeling techniques exploiting high-resolution digital images. Since there is not much information on how the temple looked like, the reconstruction was based on thorough archaeological research and the study of similar temples of the same era, both in the area and elsewhere. The proposed reconstruction is objectively criticized and evaluated for its truthfulness and usability.

As already mentioned, the interest in the cooperation of humanities and technological sciences has particularly increased in the last decades. New horizons of research have been discovered, and perspectives have appeared that were previously unthinkable, thanks to the partnership and the constant experimentation of these two scientific disciplines. In the field of cultural heritage, this collaboration has contributed to the development of specific techniques, such as virtual archaeology. As a definition, we could say that it is a set of actions aimed at obtaining, analyzing, and interpreting data that will eventually lead to the visualization and simulation of the past through the combined use of 3D digital technologies and a theoretical and multidisciplinary approach.

2. Legacy Data and Their Importance

2.1. Definition

In the eastern Mediterranean basin and especially in Rhodes, the archaeological excavation activity has been intense since the 19th century. Consequently, there exist large datasets from those excavations, published or unpublished, whose existence and exploitation has greatly assisted archaeological studies so far. With the development of the information and communication technologies (ICT), their digitization, spatial mapping, and eventual re-processing could greatly facilitate investigations of past social activities. There are also data that do not belong to the distant past of archaeology, such as excavation plans and historical maps that, in combination with other archaeological data, can be digitized, leading to a deeper understanding of the past. Such data are known as "legacy data" [1].

"Legacy data" could be defined as data mostly in analogue form, originating from non-digital sources, such as historical maps, books, and descriptions of antiquaries such as Pausanias and excavation reports. These may be considered as obsolete data, which have not been digitized or geo-referenced, and thus need to be properly digitized and processed in order to be possible to be used in a digital environment. With the rapid advancement of technology, especially as far as the acquisition of digital data (e.g., images, survey measurements etc.) is concerned, even data acquired five or ten years ago may be considered as "legacy data" as they are not fully compatible with contemporary digital processing tools.

In the field of archeology, there is a plethora of such outdated, non-digitized data, mainly from older archaeological expeditions. The re-use of digitized legacy data in GIS and other digital applications can greatly assist contemporary archaeological research. After all, almost all contemporary archaeological projects employ some form of legacy data requiring georeferencing or other digital processing, in order to be used in digital workflows.

2.2. Forms of Legacy Data

Legacy data may be encountered in various types. Re-evaluating past excavations can involve both the re-analysis of their documentation and of the various objects found, either movable or immovable, such as ruins of structures. In cases of excavation not having been backfilled, as is often the case in the Eastern Mediterranean area for touristic and other purposes, such objects should be preserved.

In many cases, it is imperative to combine metric and other data from timely different excavations or surveys; hence, ways are proposed to embark on such combinations of data, even data acquired with scale differences and perhaps at different times [2]. Sometimes, information found in previous excavation records is a result of interpretation and may falsely be considered as legacy data. Finally, it is common knowledge that over-interpretation has often occurred for a lot of excavation data, especially data originating from the classical era. These situations prove that using legacy data are often complicated because appropriate and careful processing of them is necessary before they can be digitally used.

For the proper and useful exploitation of such "legacy data", simple digitization is not adequate. Proper metadata are required, which would provide proper meaning and significance to the available data, but which are not always available or recoverable. Rodriguez Miranda and Valle Melon [3] report on exploiting old negatives for 3D model production.

Despite these and other drawbacks, legacy data contains useful information for the past, something that is not guaranteed from contemporary excavation practice. This is since in the past it was possible in many ways to perform thorough and extensive excavations because, on the one hand, it was possible to mobilize considerable manpower and, on the other, excavation periods were allowed to last longer. Hence, archaeological campaigns in the past, particularly in the Eastern Mediterranean region, were more extensive over larger open areas collecting a wealth of findings. It is this very quality that makes those legacy data useful for digital re-processing today. In addition, sites excavated decades ago may be impacted by several factors [2], such as urbanization, climate change, and protective interventions, with respect to the preservation of the in-situ findings. Consequently, digitization of older recordings of any kind have come to the rescue [1].

Undoubtedly, the data available in any form from older archaeological campaigns constitute a rich source of valuable information, especially in cases of destroyed or unavailable sites. However, their positional accuracy is very uncertain, as the means for georeferencing could have been quite inaccurate. Consequently, their digitization and re-use in contemporary georeferenced databases (GIS) should be executed with caution. An accuracy assessment should be performed for their re-use, and a careful georeference should be applied based, of course, on identifiable points of detail that can still be recognized. Accuracy assessment should always escort these actions and, ideally, should be modelled in a GIS environment to help perform proper analyses that require accurate site locations [4].

3D virtual reconstruction and visualization have greatly benefitted from legacy data. The digital reconstruction of ruined buildings has been the subject of many researchers in the recent past. It is worth mentioning the proposal by Demetrescu [5,6] of the extended matrix system to assist in these efforts. The extended matrix (EM) is a programming environment to help monitor the pipeline of virtual reconstructions. It enables related experts to document their actions towards virtual reconstruction by recording their actions that lead from available evidence to the reconstructed object. EM helps the organization of the archaeological data to support smooth, transparent, and scientifically sound 3D modelling. Very often, virtual reconstructions in archaeology result in more artistic results because of a lack of detailed information for the object reconstructed. In addition, the absence of common definitions and proper communication between technology providers and end-users, i.e., heritage experts, is another reason for this fact.

3. Virtual Reconstruction

One important domain of virtual archaeology is virtual reconstruction of cultural heritage objects. According to Seville's Principles [http://sevilleprinciples.com/, accessed on 15 February 2022], virtual reconstruction is a process conducted in a virtual environment and using a virtual 3D model that attempts to optically reconstruct a building or object that existed in the past at a given moment in time. This endeavor is supported and based (i) on available evidence about these objects, (ii) on scientifically logical comparative conclusions, and (iii) on all studies carried out by archaeologists and other experts who are working on archaeological and historical sciences [7]. A very interesting and well-presented approach to this issue is given by Ferdani et al. [8], where they focus on the exploitation of 3D digital technologies in archaeology and on the possibilities offered by computer-based visualization for the support of the interpretation and modelling of archaeological data. In this paper, the important role of 3D modelling for investigating, visualizing, and understanding the archaeological sites is stressed. The case study for the above is the roman villa of Aiano, dating from the 4th century A.D. and characterized by monumental architecture and decorations.

Pietroni and Ferdani [9] mention that virtual reconstruction denotes the representation of an archaeological object at the time of its creation or in any of the subsequent phases of its life. However, the important role in this process is played by the reasonable hypotheses that can be made. The result of the virtual reconstruction is a 3D model that will be a very useful tool for experts in cultural heritage, such as architects, archaeologists, and conservators. This model can also be used for many applications such as virtual tours, serious games, and many more. Typical implementations of 3D modelling can be found in modern physical or on-line museums and educational foundations, which aim to assist their visitors to interact in a special way with the object of interest as they are able to immerse within it or fly over it and thus examine it better, always bearing in mind its level of realism.

In recent years, many attempts of 3D virtual reconstruction have been performed, and a number of them are presented in this paper. Matini et al. [10] used a virtual reconstruction procedure for the city of Bam, a UNESCO world heritage site in Iran, which was destroyed by an earthquake in 2003. In this project, information from heterogeneous data such as photos and 3D cartographic maps was used for the reconstruction. Moreover, the symmetric geometry of the various architectural elements and their characteristic construction methods were also exploited. Lentini [11], by using several hypothetical scenarios, virtually reconstructed the rooms and structures in the front and the interior of the catacombs in the Roman necropolis of the Ponte della Lama in Canosa di Puglia. The 3D model of the ruins was built with the use of laser scanning technology. The east pediment of the Temple of Zeus at Olympia was reconstructed by Patay-Horváth [12]. Specifically, the 3D documentation was used for the creation of the 3D models of the existing figures and objects that compose the pediment. Then, they tried to reconstruct the artefacts with missing parts, and they finally composed the result, the complete 3D model of the pediment (Figure 1).

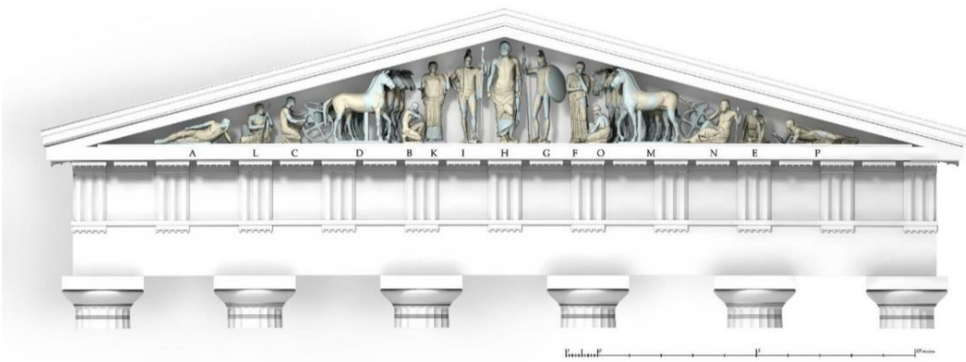


Figure 1. 3D virtual reconstruction of the east pediment of the Temple of Zeus [12].

Gkintzou et al. [13] reported on an attempt to virtually reconstructing a ruined 14–15th c. church of the San Prudencio Monastery in Spain. They geometrically documented the ruins and based their assumptions on structural observations, older texts, and artistic drawings. In addition, they introduced a verosimility evaluation of the various data available, on which they based their reconstruction.

Different kinds of data were used for the virtual reconstruction of the Middle Stoa of the Ancient Agora of Athens [14]. These data included the 3D model of the ruins and of the artefacts that constitute the sima, and architectural plans from the Stoa and from other monuments that are similar to the specific one, images, existing literature, and assumptions made by experts. Figure 2 shows the final result of the 3D virtual reconstruction of the Stoa. Guidi et al. [15] virtually reconstructed cultural heritage objects whose existing situation was 3D digitized by using range-based and image-based modelling techniques. The integration of photogrammetric reconstruction, 3D modelling, and augmented reality was implemented for the complete visualization of a fragmentary sculpture that was highly damaged [16]. A mosaic and opus spitacum floors, two of the common types of floors in the Roman Age, were virtually reconstructed. Specifically, the existing situation was digitized by implementing photogrammetric techniques. In their approach to reconstruction, they used the geometric patterns in which the floor is decorated [17]. In addition, Fazio and Lo Brutto [18] used the same approach for the virtual reconstruction of the Sanctuary of Isis in the ancient Lilybaeum in Italy.

Figure 2. Virtual reconstruction of the Middle Stoa [14].

A 3D virtual reconstruction of an ancient hydraulic tunnel construction, which is not visible any more today and for which no original fragments of the ruins are available, was conducted with the use of heterogeneous data from different sources [19]. Finally, the technology of virtual reconstruction is used in cases of ancient cities, such as in the case of the historic city of Al-Zubarah in Qatar [20]. Recently, Abad et al. [21] have reported on the interesting case of the virtual reconstruction of a Medieval Castle in Galicia, Spain. This study exploits the findings of the research conducted, to create a reasonable hypothesis for the form of the castle and its reconstruction in a digital model, as a means to interpret and understand its structure. For that purpose, the authors exploited the examination of the archaeological data and the hill geomorphology, the study of similar fortresses, and the application of architectural specifications. Their objective was to produce a reasonable, justified, and scientific model of the castle that would be useful as an instrument to study and comprehend this type of construction.

4. The Temple on the Acropolis of Agios Fokas

About 70 km south of the city of Rhodes, in a semi-mountainous and wooded area, lie the remains of an ancient municipality of Rhodes, little known until today [22] (pp. 285–298), [23] (pp. 83–84), [24] (pp. 236–242), [25] (pp. 124–129), [26–30], [31] (pp. 58–71), [32]. This is the ancient deme of the Kymissaleis (Figures 3 and 4).

Figure 3. A map of Rhodes Island based on a satellite map of Rhodes, Laboratory of Cartography and Geographic Information Systems, University of the Aegean. Available online: https://www.lib.aegean.gr/doryforikos-hartis-rodoy (accessed on 20 November 2021).

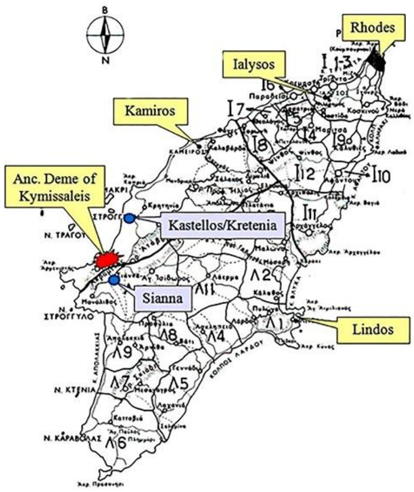


Figure 4. Rhodes. Maps with ancient sites, and the location of the ancient municipality of Kymissala and modern villages [31,33], are shown.

It is a natural landscape of incomparable beauty with fertile plateaus and valleys and extensive forest areas. In a wide geographical context that extends between the mountain Atavyros in the north-northeast and Akramytis in the south, the sea to the north and the country road to the local communities of Sianna and Monolithos to the east, there are numerous interconnected archeological sites covering an area of about ten square kilometers [22] (pp. 285–298), [23] (pp. 83–84), [24] (pp. 236–242), [25] (pp. 124–129), [26] (pp. 86–92), [27] (pp. 263–264), [28] (pp. 10–16), [32].

The hill of Agios Fokas, which is the acropolis of Kymissala, is the epicenter of all antiquities. The acropolis dominates the wider area and allows for visual contact with a major part of the region. On the top lie the remains of a Hellenistic temple. Several travelers and archaeologists visited the antiquities of Kymissala, and some of them reached the hill of Agios Fokas and recorded the temple of the acropolis in their essays. The most important studies to date concerning the temple were made in the early 20th century and specifically in 1905 and 1915 by the archaeologists Kinch [25] (pp. 124–129) and Maiuri [22] (pp. 285–298) and [23] (pp. 83–84), respectively. In September 1905, the Danish archaeologist Karl Frederik Kinch visited Kymissala. During his tour, he recorded and designed the antiquities of the area, including those on the hill of Agios Fokas. Kinch made the first systematic description of the ruins of the temple, with measuring details and drawings.

On the occasion of the research of the Italian Archaeological School in the central and western areas of the island of Rhodes, it was proposed in 1915 to the archaeological mission to give priority to the study of sites less accessible and more neglected. The aim was to solve some of the problems and questions that still existed regarding the antiquities of the island. As part of these excavations, Amedeo Maiuri conducted a surface survey and a small excavation in the temple and in the central necropolis of Kymissala in 1915. His work on the acropolis of Agios Fokas is the most detailed study of the temple to date [22] (pp. 285–298). The Italians also restored a number of blocks of the second row of stones of the north wall masonry to their original position [22] (p. 292, Figure 9), which today have fallen off again, apart from the corner one, possibly due to a 20th century earthquake [32].

Apart from the excavations of the Italian Archaeological School at the beginning of the 20th century, the excavations carried out in the following decades in the area of Kymissala were limited. These were mostly rescue excavations and small-scale clean-ups carried out by the Ephorate of Antiquities of the Dodecanese. As part of this, in 1975 the acropolis of Agios Fokas was cleaned under the supervision of archaeologist Konstantinos Katralis [26] (p. 69). In 2006, the Department of Mediterranean Studies of the University of the Aegean started the Kymissala Archaeological Research Project (KARP) in collaboration with the Ephorate of Antiquities of the Dodecanese, under the direction of Professor of Classical Archeology and Numismatics, Manolis I. Stefanakis, and archaeologist Dr. Vasiliki Patsiada. The Laboratory of Photogrammetry of the School of Rural, Surveying, and Geoinformatics Engineering of the National Technical University of Athens [27] (pp. 302–306), [34–36] and the Institute of Archaeology of the Nicolaus Copernicus University in Toruń, Poland also participate in the project, which is continuing to this day [26–30,37–39].

After the cleaning, which was carried out in 1975 by the Ephorate of Antiquities of the Dodecanese, a large part of the temple was covered with dense bush vegetation. In fact, the roots of the bushes have caused detachments or stone displacements of the temple's masonry [26] (pp. 72–73), [32]. In 2006, at the beginning of the Kymissala Archaeological Research Project, a clearing of vegetation was carried out, both in the area of the temple and in the fortified precinct on the western slope. During the clearing process, fragments of tiles and a few shells of the Hellenistic period, mainly unpainted, were collected from inside the temple. A fragment of a column drum and a fragment of a Doric capital (Figure 5a,b) were also found, but the small size of the columns from which they seem to come indicates that they do not belong to the temple but probably to another building of the acropolis, perhaps a portico. In addition, the upper surface of the facade wall foundation from the surviving in situ upright shaft to the south wall of the pronaos was found (Figure 6), an element that did not exist in the Italian plan view [26] (p. 73).

(**a**)

(**b**)

Figure 5. Fragments of a Doric capital (**a**) and a column drum (**b**) [26] (p. 104).

Figure 6. The foundation of the wall of the temple façade [26] (p. 104).

The temple (Figure 7) is built on the flattened natural rock, which in some places lies almost at the level of the floor of the cella, while in the pronaos it is located about 2 m lower. It is a Hellenistic temple of the 3rd–2nd century BC with external dimensions approximately 13.50 m in length and 5.80 m in width. It has an E-W orientation with an entrance to the east and consists of a closed deep pronaos and a cella. Only the lower course of stones has been preserved, while stones from the second row of the north wall are found inside the cella [22] (pp. 291–295), [23] (pp. 83–84) [25] (pp. 126–128), [26] (pp. 72–74), [27] (pp. 265–266), [30] (pp. 567–569). During the Italian excavation of 1915, an attempt was made to relocate some stones of the second row to their original position [22] (p. 292). The height of the two courses was calculated 1.22–1.23 m by Maiuri [22] (p. 292), but the total height of the temple is unknown. The temple is made of local gray limestone, known as lartios stone (*λάρτιος λίθος*) (Greek). These are rectangular stones that have intense kyphosis on the outside and traces of peritaenia [26] (p. 73), while inside they are irregular, and they probably consisted of small stones. Perhaps the masonry at the top of the walls was similar. Both on the facade and on the rear side, the long walls of the temple have semicircular ends because of the intense kyphosis of their stones [22] (p. 292), [26] (p. 73), creating a kind of semi-circular pilasters at the four corners. On the front, the semicircular ends have traces of irregular vertical glyphs, referring to half-columns [26] (p. 73). A large rectangular upright shaft lies in situ and in contact with the north pilaster of the facade [27] (p. 292), [26] (p. 73), which, together with a second one that was probably in contact with the south pilaster, framed the door. The large monolithic threshold of the entrance to the cella made of light-colored limestone with incisions, measuring 1.60 × 0.65 m, is also preserved in situ.

Figure 7. The ruins of the temple on the Kymissala acropolis.

Kinch recorded the traces of the enclosure outside and around the temple at a distance of 11.30 m from the north wall, 11.40 m from the east, and 6.40 m from the south [25] (p. 128), while Maiuri also observed the traces of an ancient demarcation [22] (p. 293). No recent traces of the enclosure were found during the latest research. The deity to whom the temple was dedicated is not known. Maiuri believed that the temple was dedicated to the Demeter according to the unconfirmed information of residents. In his memoirs, however, he refutes this case, considering it more likely that the temple was dedicated to Diana (Artemis). This view was based on the one hand, on the name of the neighboring mountain "Artamitis" (obviously, incorrect reference to Akramytis) and, on the other hand, on the forest and the spring at Stelies, which were sacred and dedicated to Artemis, as well as on the presence of deer [39] (p. 129), [26] (p. 74). Opinions differ regarding the statue of the temple. Berg recognized a clothed female statue of colossal size [40] (p. 152), while Newton spoke of a female marble statue with white legs garment, badly damaged and fallen to the side of its base. Its height was about 3.048 m (10 feet), and its base was 1.27 m (4 feet and 2 inches) by 1.092 m (3 feet and 7 inches) [41] (p. 203). Biliotti and Cottret [42] (p. 87) recognized a male marble statue with a surviving length of approx. 1.50 m, and they identified it with Apollo [43] (p. 41).

The individual morphological and architectural elements do not allow for the exact determination of the form of the temple on the acropolis of Kymissala, due to poor excavation findings. Nevertheless, it seems to be a simple single temple without columns. The oldest and simplest form of ancient temple is characterized as a ''simple temple", being the evolution of the structure of the "mansion", and consists of an elongated rectangle space, where its long walls extend in the shape of semi-circular pilasters and include the cella and the pronaos. As there are no indications for the existence of columns from the available data, the temple is characterized as astyle. This literally means "without columns" and is used for temples whose pediments rest only on pillars. Although some geographical and chronological related examples are not known, the surviving data, the simple structure, and the existence of a closed pronaos bear similarities with the Temple of Zeus, the Hiera Oikia (Sacred House) at Dodona [44].

In general, it can be suggested that the Temple of Zeus belongs to the simplest type of temple, in the form of a mansion, a type that is found throughout Greece in rural sanctuaries and in remote areas [44] (p. 38). In addition, the oldest temple of Aphaia in Aegina [45], which dates to 570–560 BC, belongs to this type. At this point, it is worth mentioning that the identical ancient Greek words *οἶκος* and *οἰκία* usually denote human habitation, but sometimes they also acquire special significance. They were also used for the main buildings of worship. An archaic inscription [45] (p. 367, Figure 292) refers to the ancient simple *in antis* temple of Aphaia in Aegina as a house.

Furtwängler notices that in a later period, from which the epigraphic examples originate, mainly closed buildings of secret worship, without the outside columns and therefore similar to ordinary homes, were characterized by this word. The building on the western slope of the Acropolis [46] (p. 172) could be mentioned as a temple belonging to the simple type of mansion. This is an archaic temple of small dimensions and consists of a closed pronaos and a cella.

The temple of the acropolis at Kastri in the Grevena Prefecture [47] presents a similar form of mansion and facade probably without columns. This structure is dated to the late 4th or early 3rd century BC and consists of a narrow pronaos, a cella, and probably another narrower opisthodomos (an element that does not correspond to the data of Agios Fokas). From the building remains, it appears that the temple was made of stone and had a tiled roof. The research carried out to date has not produced any finds that would allow for a valid description of its form. It seems, however, that it is an astyle temple in the type of mansion (*οἶκος*).

Small in size, astyle, which conforms to the type of oikos (mansion), is also the temple from the sanctuary of Eukleia at Aigai [48]. The small temples of Hercules, Aphrodite, and Dione, from the sanctuary of Zeus at Dodona [49], could also be mentioned as examples of this form. The temple of Athena and Zeus in Figalia [50], [51] (pp. 43–49, 51–53) presents common elements with the temple on the acropolis of Kymissala. It probably dates back to the 4th century BC, and it is built according to the irregular isodomic system. The entrance is at the East and, like the temple on the hill of Agios Fokas, it consists of a pronaos and a cella, to which one enters through a monumental monolithic threshold with distinct incisions for fixing the pilasters of the door.

In summary, the temple on Agios Fokas is a relatively small building, consisting of a closed deep pronaos and a cella. The pronaos communicates with the cella through a monolithic threshold, where incisions can be seen, most likely for the fastening of the wooden door's pilasters. A characteristic element of the temple is the semicircular ends of the walls, which create a kind of semi-column at the four corners. On the front, the semicircular ends bear traces of irregular vertical glyphs, referring to half-columns. From the fragments of the tiles found during excavation, the existence of a tiled roof is confirmed, but whether the tiling is of Corinthian or Laconian type cannot be determined.

As no superstructure elements have been found, it is difficult to certify the rhythm to which the temple belonged. The fragment of a Doric capital identified in recent research cannot be placed in the temple with certainty. From the information gathered, it was a temple with closed pronaos, while there are no indications of the existence of columns in antis. There is the possibility that the capital came from half-columns that framed and decorated the entrance door, in the style of the Macedonian tombs. As generally no ornaments or decorative sculpture elements have been found, it is most likely that the temple was unadorned as a whole and did not have an ornate entrance. Possibly, the capital comes from another building on the acropolis, perhaps a portico or an ex voto around the temple but may also have been the crown of the corner semicircular pillars.

It has been made clear that for the particular temple there are very few, if any, available and usable legacy data, perhaps with the exception of the sketches by Kinch [25] and Maiuri [22] and a short reference to the dimensions by Biliotti and Cottret [42]. In the absence of sufficient data, we cannot be led to a detailed view of the exact form of the temple in Agios Fokas, but it is possible to consider it as an "Oikos", like the Temple of Zeus at Dodona, with which it presents several common morphological elements. The systematic excavation of the temple is expected to reveal new finds and enlighten many aspects related to the structure and morphology of the temple and to the deity to which the temple was dedicated.

5. The Geometric Documentation and the Creation of the 3D Model

5.1. Fieldwork—Data Acquisition

The geometric documentation of an archeological monument is a process that requires, on the one hand, careful work and measurements and, on the other hand, respect for the site. The execution of any action must be performed with respect to the particularities and limitations of each site; therefore, the primary element is the reconnaissance of the wider region and the object to be documented. The present study, which aims at geometric documentation of the temple on the Kymissala acropolis and the creation of a three-dimensional model with its virtual reconstruction, was carried out exclusively through implementing the photogrammetric method by taking digital high-resolution images. The main reason was the limited time available for field work, on the one hand, and the experimental application of a relatively simple and semi-automatic method that does not require highly specialized knowledge and therefore can be used by non-specialists, on the other hand.

The equipment used for the fieldwork included the Canon EOS 6D full frame and the Canon EOS 80D with APS-C sensor digital SLR's, with 6.6 μm and 3.8 μm pixel pitch, respectively. With these cameras, the following lenses were also available: 50 mm, 35 mm, 135 mm, and 1–135 mm. The fieldwork in the temple was completed in one visit, with the purpose of taking measurements, photos, and the necessary data for the implementation of image-based modelling employing the SfM/MVS (Structure from Motion—Multi-View Stereo) process. The short duration of the work demonstrates the efficiency and convenience provided by the new technologies regarding the geometric documentation of monuments. The first actions in the field concerned the study of the monument and the surrounding area. This primary phase is of major importance as it contributes to the better perception of the space and the identification of the details and the peculiarities of the monument, to achieve the proper planning of the photography phase and the positioning of the pre-marked targets in specific spots inside and outside the temple in such a way as to embrace the whole monument (Figure 8a). These targets, which were positioned in a completely reversible manner, i.e., using blu-tac, would provide information for scaling the model subsequently. Thus, only the three-dimensional distances between almost all possible pairs of them were measured using a simple measuring tape. Specialized targets were used, which would enable their automatic recognition and location by the processing software later (Figure 8a). Photography was conducted in such a way as to facilitate the automated image-based modelling process afterwards, namely, with large overlap, adequate GSD (Ground Sampling Distance), and by making sure that all details of the object were imaged in at least three images. Hence, various lenses were used for the process. For levelling the 3D model later, a steel measuring tape was positioned vertically at a nearby trigonometric pillar (Figure 8b).

In the present study, the selection of shooting locations was not always easy as some obstacles were present. The dense vegetation in places, especially on the east outer side of the temple, resulted, on the one hand, in taking some shots with difficulty and from unfavorable positions and, on the other hand, in inevitably them being present in many photographs.

(**a**)

(**b**)

Figure 8. (**a**) Pre-marked target. (**b**) Levelling information.

5.2. Data Processing

For processing of the data obtained during the fieldwork, the Agisoft Metashape and Geomagic Studio software were used. The combination of modern recording methods to carry out the work proved to be particularly useful, leading to a realistic and accurate result. This task involves the data processing to produce the 3D textured model. The necessary steps concern the processing of the data obtained during image acquisition; the production and processing of the 3D model; and, finally, the presentation of the results, which is the most basic stage of the whole process. Below, the steps followed for the final production of the 3D model are presented.

All 582 images acquired were loaded in the software (Agisoft Metashape) in one chunk, from which the ones of lesser quality, i.e., blurred or badly illuminated, were removed. To achieve an optimal result, masks were manually placed on the images to exclude unnecessary information material (such as the sky) during processing, which can create noise or errors in the final product. Then, in the images, the special photogrammetric targets whose distances between them had been measured, the so-called "markers" that were placed in the monument, were automatically identified and checked in terms of their position and numbering. Following that, the process of orienting images, i.e., "align photos" was carried out, where the software orients the images, specifying the relative positions among them. The common points in the images are automatically located and placed in correspondence with each other, while at the same time the positions of the camera in 3D space are determined (Figure 9).

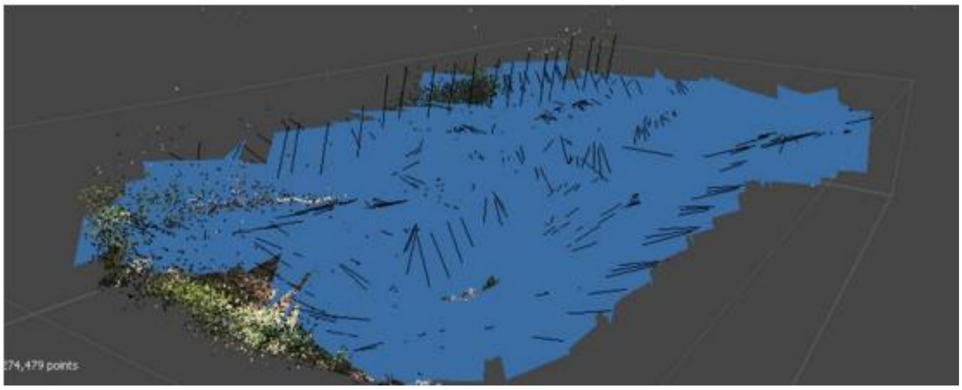


Figure 9. Sparse cloud of points and shooting locations.

The 3D distances between the pre-marked targets were introduced, to scale the final model. The sparse point cloud was checked for accuracy and completeness, and some deficiencies were found in certain areas of the monument. It was decided to follow the same procedure in a separate chunk with the 43 images from the Canon 80D, which depict areas of the study object that are not depicted in the images taken by the Canon 6D. The two different chunks were later combined and merged for creating a single sparse point cloud. The two digital cameras, despite their main difference of the sensor size, present similar pixel sizes and, consequently, they could be considered interchangeable. The two cameras were used almost simultaneously to speed up field work.

The next step was to create the "dense point cloud". The software creates a dense point cloud, based on the camera's estimated positions; calculates the depth map for each image; and combines them into a single dense cloud. The resulting point cloud was cleared of unnecessary information using the tools provided by the software. Figure 10 illustrates the final dense point cloud of the temple.

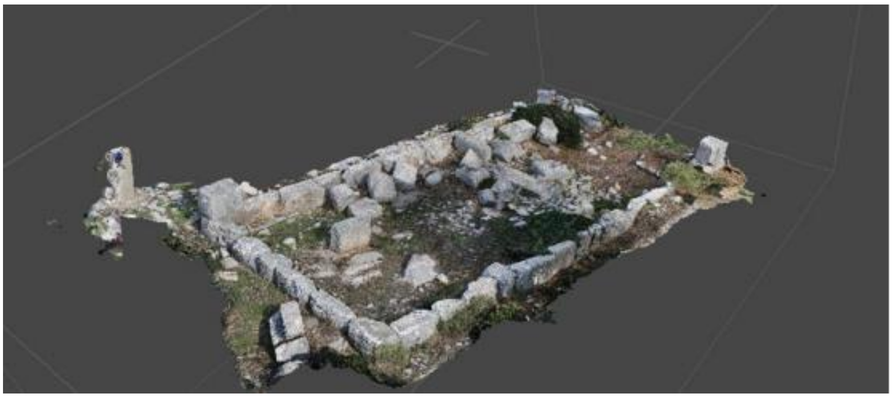


Figure 10. The dense point cloud, viewed from the NW side.

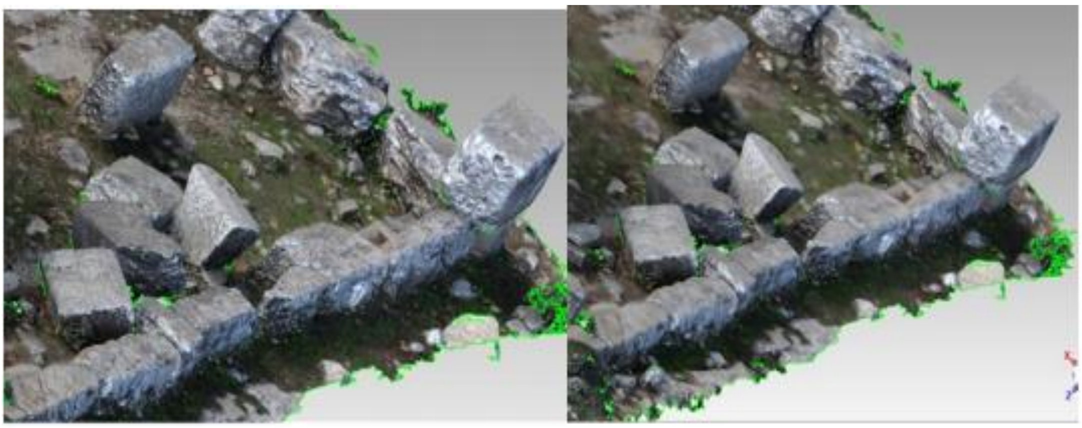
Then, the surface of the temple was created using the "Build Mesh" command. More specifically, the software has two options for creating the surface, which depend on the point cloud to be used (dense or sparse). In the case of the temple, its surface was created based on the dense point cloud as this provides a more detailed description of the monument. Figure 11 shows the 3D model of the temple.

Figure 11. 3D model surface viewed from the SE side.

The surface was then exported from the Metashape software and imported into Geomagic Studio to reduce its resolution, to make it manageable by the software to be used for the virtual reconstruction.

5.3. Processing of the Point Cloud

The surface of the temple was extracted from Metashape software to be imported into Geomagic Studio software for the reduction of its resolution by decimation. The reason for this reduction was to make the 3D model manageable by the software to be used in the next step for the virtual reconstruction of the monument. The "decimate" command tries to lower the resolution of the model by reducing the number of triangles that make it up, while trying to preserve many of the details of the object, especially in cases where its surface is more complex. In the case of the temple and since the software to be used for the virtual reconstruction cannot cope with the high-resolution models, it was decided to reduce the model, so that it retained 30% of the information (Figure 12). The 3D model was then re-introduced into Metashape for texturing. This process requires the use of the 3D model in the visualization software. The original high resolution of the 3D model was retained for its metric exploitation, including the production of cross-sections, and accurate 3D measurements.



(**a**) (**b**)

Figure 12. 3D model before (**a**) and after (**b**) reduction.

This stage is the final step for creating the 3D model. To render the texture and color of the object, the software looks up in the digital images that were inserted and renders the colors of the real object on the created model. The most suitable method was used, with which the software tries to give the most homogeneous texture to the model, without making assumptions about the type of part being reconstituted. This method allows for the parameterization of the texture for arbitrary and random surfaces. Other parameterization options provided by Metashape for texture rendering are color correction (Enable color correction), which is extremely time-consuming, and its use is recommended only in cases where the data show poor-quality results, and the filling or closing of holes (Enable hole filling), which is the default setting to prevent salt-and-pepper noise, i.e., white and black pixels appearing sparsely. The default settings have been retained, and the results are shown in Figure 13.

Figure 13. Three-dimensional textured model.

The 3D model is now available for many applications, such as virtual reconstruction, which was the main goal for this temple. In addition, the 3D model could be exploited for extracting metric information, producing orthophotos, 3D printing, or use in game engine environments for the development of VR applications and serious games. Digital technologies allow such processes, which suggests that they take place in a three-dimensional space, commonly called a virtual environment, and the final product is the three-dimensional virtual model [52]. The main advantage of virtual reconstruction is the ease with which one can intervene in the model and make changes, modifications, and improvements [52]. The current possibilities of digital technology allow for virtual reconstruction where architectural methods inevitably stop. If the user is familiar with the operational mode of the software used, the virtual reconstruction can render the original or other desired form of the monument in three dimensions. At the same time, it contributes significantly to the work of scientists on each monument and especially in those areas where technical difficulties or internationally applicable restoration principles do not allow for intervention.

5.4. Considerations for the Virtual Reconstruction of the Temple

The virtual reconstruction of the temple of study was not an easy task. To begin with, there were absolutely no records of its form and particular characteristics. In addition, no direct parallels of the same era were found either in the area, in greater Rhodes, or in the neighboring islands. Hence, the virtual reconstruction was based on the available data, which were supplemented by scientific and interpretive hypotheses related to the architectural style of the period, as well as to the temples with parallel architectural elements [53]. For the 3D reconstruction, it was decided to firstly construct a rough 3D model in SketchUp software [https://www.sketchup.com/, accessed on 15 February 2022] and later to adapt that to the existing situation for the necessary refinements of the final proposal to be realized in 3ds Max software [https://www.autodesk.eu/products/3ds-max/overview, accessed on 15 February 2022]. Figure 14 shows the flow of all the types of software used and their sequences.

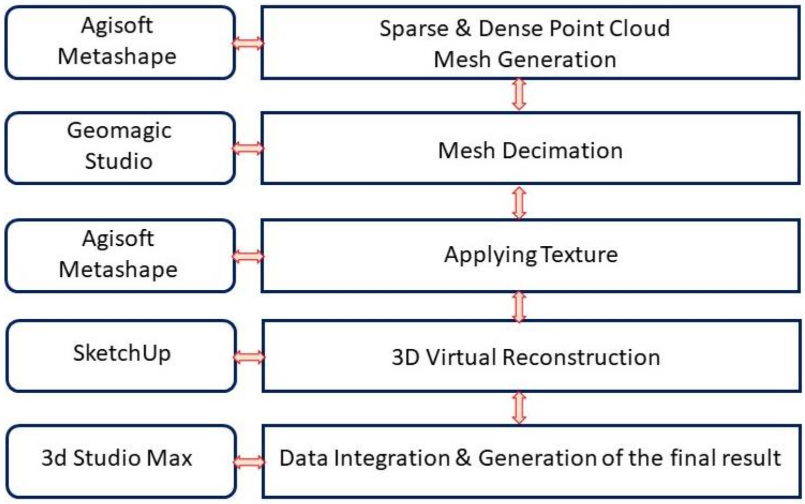


Figure 14. A flow diagram of all software used [53].

Regarding the limitations and difficulties that may arise in research, we should especially focus on the case of monuments, which are characterized by a lack of sufficient information. Many of the 3D architectural models are reconstructions of buildings that no longer exist or are not fully documented. It is therefore inevitable that these reconstructions contain a small or large percentage of hypothetical elements characterized by varying degrees of uncertainty. In the case of the Hellenistic temple on the acropolis of the ancient Demos of Kymissaleis, a monument with an almost complete lack of architectural elements and very few references, the reconstruction was largely based on interpretive assumptions related to the architectural parallels, as well as to the architectural style of the chronological period.

SketchUp is a 3D modeling software with a wide range of design applications. It was selected for the virtual reconstruction of the temple in Agios Fokas due to its simplicity. Using the basic set of tools and the manual measurements provided by Maiuri [22] and Kinch [25], the temple was designed from scratch within the software's environment. Architectural parallels of the same period were also consulted to assign the correct characteristics to the reconstruction (Figure 15).

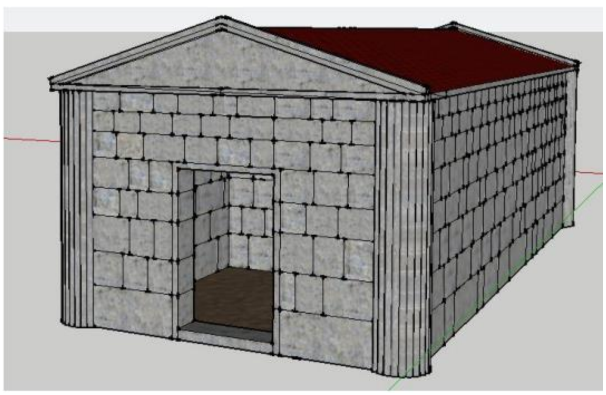


Figure 15. The temple as designed with SketchUp software.

As already mentioned, the lack of sufficient excavation finds does not allow for the precise determination of the form of the temple, despite the individual architectural and morphological elements. Archaeological research so far has not provided a sufficient number of architectural members and fragments, which could lead with certainty to the description and design of the entablature, the roof, the door, or the floor of the temple. Likewise, it is not easy to determine the height of the temple. Therefore, the virtual reconstruction proposed in the present work has a simple character, without specific and detailed morphological elements. As no special architectural members or decorative elements have been found, it is difficult to classify the temple as belonging to a certain order. Consequently, the form of the frieze, the pediment, and the entablature in general cannot be certified. It is possible to assume that the form over the semi-circular pilasters was simple and unadorned, as in the case of the "Hiera Oikia" (Sacred House) in Dodona [44], with which the temple of Agios Fokas presents many morphological similarities. In the present study, a virtual reconstruction of the temple as an "Oikos" is proposed, without elements of decoration or decorative sculpture (Figure 16).

(**a**) (**b**)

Figure 16. The facade of the temple at 3ds Max (**a**) and SketchUp (**b**).

The fragments of clay tiles that have been found constitute illuminating elements for the roof of the building. The temple clearly had a clay tile roof, but as whole tiles have not survived, so we do not know the exact type to which they belonged, i.e., whether it was a Laconian or Corinthian tile type. For this reason, no tiles were designed during the reconstruction process, and the ready-made roof sample in the SketchUp collection was placed by adjusting the color (Figure 17).

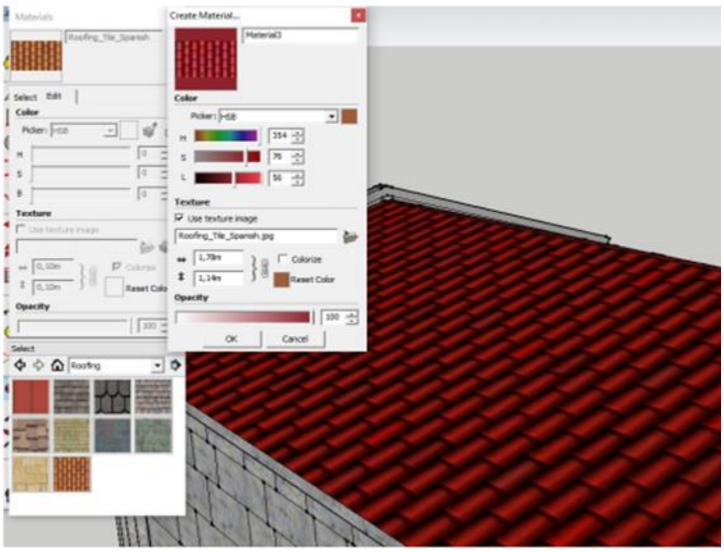
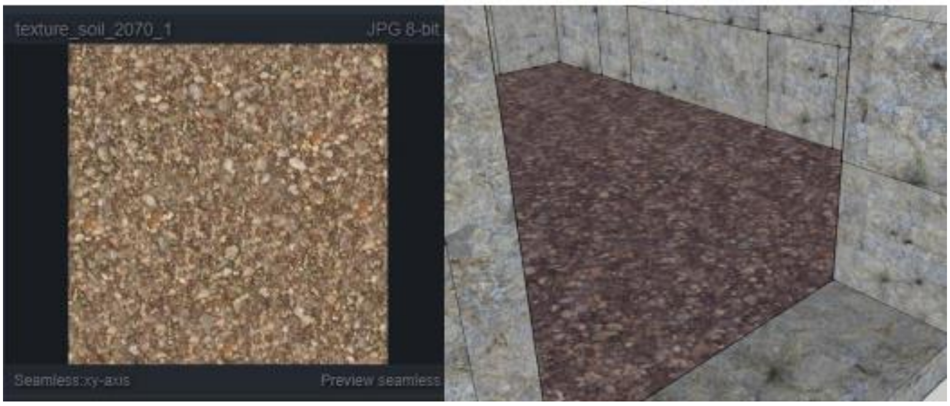


Figure 17. Creating the roof in SketchUp.

Likewise, there are no clear indications regarding the shape and composition of the floor. The surviving data do not indicate the existence of a structured floor in the temple. Hence, since no traces of artificial mortar or clay tiles have been found to cover the floor, we can assume that this was probably an earthy ground. An image from the plaintextures.com [https://plaintextures.com/, accessed on 15 February 2022] page (Figure 18) was selected for the texture rendering on the floor.



(**a**) (**b**)

Figure 18. Floor texture image (**a**) and placement in SketchUp (**b**).

A suitable image from textures.com [https://www.textures.com/, accessed on 15 February 2022] was selected to render texture to the structures. The selection criterion was the most faithful representation of the texture and color of the grayish limestone (stone of stone), from which the temple is made (Figure 19). It should be noted that the joints of the course of stones, while visible in SketchUp, are not visible in 3ds Max.

(**a**) (**b**)

Figure 19. Texture image (**a**) and grayish limestone from the temple (**b**).

The height of the temple was another point of concern for the current reconstruction. In the absence of other concrete data, it was calculated approximately according to the "golden ratio". Hence, for the front façade, the ratio of the structure's height to its width was set to 5:8, as dictated by the "golden ratio".

The incisions that are distinct in the large monolithic threshold leading to the cella are probably related to the fastening of the wooden door pillars. Based on this observation, a wooden door was placed at the entrance of the cella with an image from the textures.com page [www.plaintextures.com, accessed on 15 February 2022] (Figure 20). Respectively, a monolithic threshold was placed in the pronaos.

Regarding the angular semicircular pilasters, two reconstruction proposals are proposed in the present study. In the first case, the pilasters remain undecorated, ending at the cornice of the temple (Figures 21–23). In the second case, taking into account the possibility that the Doric capital found in the acropolis belonged to the temple, the pilasters are crowned with it, referring to half-columns (Figures 24 and 25).

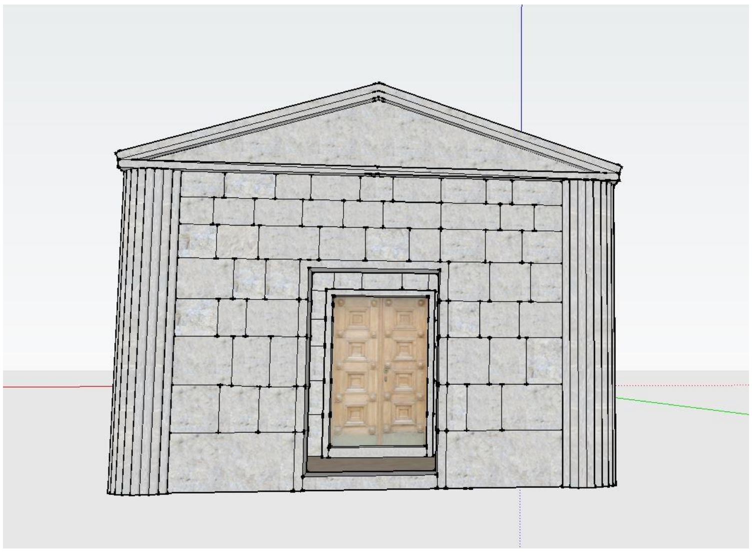


Figure 20. Door at the entrance of the cella.

Figure 21. Reconstruction proposal with unadorned pilasters.

Figure 22. Reconstruction proposal with unadorned pilasters (front).

Figure 23. Reconstruction proposal with undecorated pilasters (rear view).

Figure 24. Proposal for the reconstruction of the pilasters with a capital, referring to half-columns.

Figure 25. Proposal for the reconstruction of the pilasters with a capital, referring to half-columns (front).

The two 3D models, i.e., the one depicting the current situation as well as the one that emerged after the 3D reconstruction process, were subsequently imported into the 3ds Max software for merging them in order to finalize the result of the virtual reconstruction. 3ds Max is a commercial 3D graphics software by Autodesk [https://www.autodesk.eu/products/3ds--max/overview?term=1-YEAR&tab=subscription, accessed on 15 February 2022], where the user may create 3D models, animations, and games. Initially, the textured 3D model that emerged from Agisoft Metashape was exported in obj format and imported into 3ds Max without any problems (Figure 26).

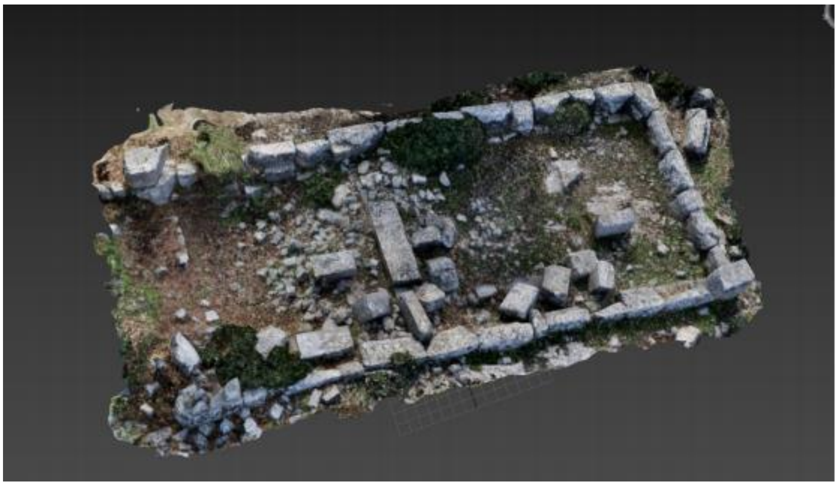


Figure 26. 3D model of the current situation at 3ds Max.

Then, the two proposals concerning the virtual reconstruction that took place in a previous step were imported. 3ds Max can handle files that have been created by SketchUp software, so no further conversion of the files was required for the process. As shown in Figure 27, the 3D model was in a different position from the current situation.

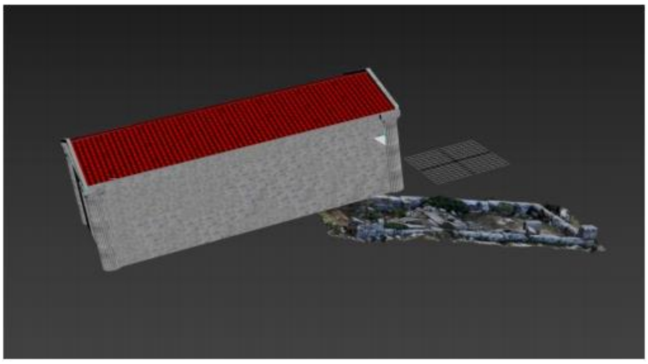


Figure 27. 3D reconstruction model as imported in 3ds Max.

Then, with the rotating and shifting tools provided by the software, the 3D model was placed in its correct position in relation to the current situation. The same procedure was followed for the second reconstruction proposal presented. Figure 28 shows the final result. The determination of the detailed architectural features of the temple has been a difficult issue, as many basic and sub-morphological elements are uncertain or even unknown. In this section, an analysis of the reasoning and interpretive hypotheses has been attempted, on which the design and consequently the virtual reconstruction of the temple on the Kymissala acropolis was based.

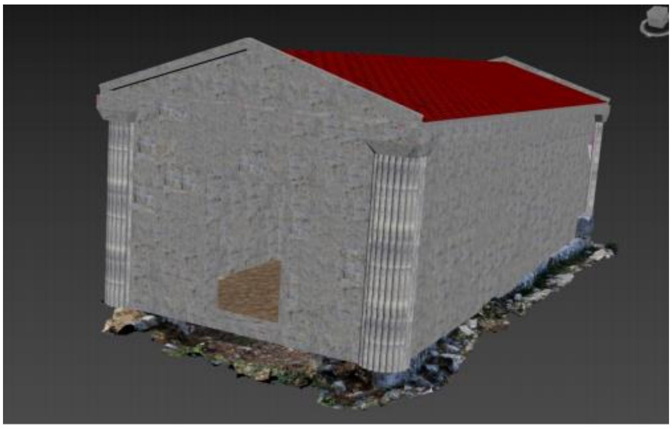


Figure 28. 3D reconstruction model in its correct position.

6. Evaluation and Concluding Remarks

The process followed for the creation of the 3D model and the virtual reconstruction of the temple proved to be very time consuming but at the same time very interesting [45] as it involved archaeological research supported by innovative technologies. It consisted of several stages, which were analyzed in detail above. Regarding the data collection, which included taking the necessary measurements and the images, it was quite satisfactory in relation to the time available for conducting the field work. It has been proven that contemporary data acquisition procedures require only a fraction of the total time compared to in the recent past, and less personnel, albeit with some skills.

The creation of the three-dimensional model and the virtual reconstruction of the temple on the Kymissala acropolis was demanding and at the same time didactic both in terms of applying the respective methods and of assisting the archaeological interpretation. Considering the available data and despite the practical difficulties and methodological limitations encountered, as well as the shortcomings identified, the results can be considered as very useful in terms of experimenting with different reconstruction scenarios and are sufficiently satisfactory considering the available data. The 3D textured model produced has greatly assisted the reconstruction as the impression offered to the experts while experimenting with the various alternative solutions was far more realistic than just observing them in a 2D representation.

The main factors that made the process time consuming were clearly the time necessary to conduct the bibliographic research to decide for the most probable form of the temple, as well as the time required for the data processing by the various software. Many of the processes were repeated several times until the required final result was achieved. In addition, during the data collection process, unnecessary information was inevitably collected, but it was removed through appropriate software tools. The biggest difficulties of the present study, however, were related to the monument itself. The absence of sufficient excavation finds made the process of design and virtual reconstruction of the temple difficult. In the absence of substantiated evidence, the result was largely based on hypothetical interpretations. Therefore, further study of the temple is deemed necessary. Despite the difficulties, the whole process was an occasion for better exploitation of the new technologies and especially the steps that are followed during the geometric documentation of a monument. The main objective of the project was to propose the most reasonable reconstruction of this temple, of which very little previous data were available. Additionally, one could improve the rendering process and end up with a more realistically rendered 3D model with better texture and by exploiting finer computer graphics and illumination rules to convey the impression to the observer.

The virtual reconstruction of the temple has been an enlightening experience, especially in terms of how a monument is approached by disciplines other than archaeology, such as surveying and geomatic engineers. It has become clear in practice that interdisciplinary cooperation can help broaden the perspective with which the object to be reconstructed is approached and maximize the success of the final virtual reconstruction. The use of new technologies and digital methods in general proved promising and has rapidly changed the traditional documentation techniques. Especially, 3D modelling has attracted the interest of scientific circles in recent years as it allows for the reconstruction and visualization of monuments and cultural heritage sites. On the other hand, legacy data undeniably are a valuable source of information for monuments and their lifecycle. Contemporary technologies have enabled their advanced exploitation by expanding their usability in digital form. Consequently, and provided they are digitized in a proper way, legacy data could offer new tools and information sources in the never-ending study and interpretation of the human past.

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