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https://dx.doi.org/10.15496/publikation-88491

Viability of Production and Implementation of Retrospective Photogrammetry in Archaeology

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Abstract

Retrospective photogrammetry is a novel approach to producing fully functional three-dimensional models using archival photographs, plans and drawings augmented with contemporary photogrammetry and surveying. This paper addresses the advantages as well as the difficulties in using retrospective photogrammetry and examines how the results can be put to use for further research, preservation, restoration, monitoring rates of deterioration and presentation to the public. We examine the approach to retrospective photogrammetry from the perspective of both the photogrammetrist and the end user (ie. researcher, scholar or authority responsible for using or disseminating the resulting data).
From the perspective of the photogrammetrist it is the nature and quality of the archival data that is of concern. Does the archival material meet the needs of 3D modeling and will the resulting models meet the needs of the end user? The end user is concerned with being able to store, access and utilize the results constructively. An impressive 3D model without detail or metrics is of little use apart from public presentation. We explain why the end user's goals must be addressed clearly prior to commencing the project.
We will look at examples from the Athenian Agora and Ancient Corinth to illustrate the methods required, limitations experienced and opportunities made possible with the resulting products.

Keywords: Retrospective Photogrammetry, Photogrammetry, 3D Modelling, Archival Photographs, Archaeology

Introduction

Retrospective Photogrammetry is a method of producing metrically accurate three dimensional models by using archival photographs, drawings and data (Wallace 2017). When applied to archaeological sites and monuments, the resulting models can be used to aid in conservation, rehabilitation and restoration of sites as well as aiding in ability to study these excavations as they were and in some cases, examine sites that no longer exist (Gruen et al. 2002, Falkingham et al. 2014, Lallensack et al. 2015,Wilson et al. 2016, Wallace 2017, Maiwald et al 2017, Zawieska et al. 2017, Wolter 2018, Condorelli and Rinaudo 2018, Wallace 2021, Panagiotopoulou et al. 2023). In this paper we examine both the viability of retrospective photogrammetry and whether there are justifiable benefits to it. We will do so using examples from the Athenian Agora and Ancient Corinth.

Retrospective Models

Fountain of the Lamps

One of the first examples to be examined has been the fountain of the lamps in Ancient Corinth. First discovered in 1968 by James Wiseman, the fountain of the lamps was a rich, robust archaeological site with a main swimming pool and covered bath areas built into

Figure 1. Fountain of the Lamps 3D modelling in 2012

the bedrock and supplied by natural springs. While the site was able to survive intact since the late third century b.c.(Wiseman 1970), once excavated, deterioration began. Currently, the bath areas have collapsed and the pool area is inundated with reeds and fig trees. Walls have fallen and the entire area cannot be studied safely in its present state. Wiseman found that "other connecting structures, almost certainly including a fountainhouse, were in use during the late third century b. c. and into the next century" (Wiseman 1970). He, as an end user of photogrammetry, has expressed a desire to re-examine certain aspects of the site that are no longer available. We have all photographed elements and events at a time when we felt we had fully documented them only to find afterwards that there are gaps in our recording. Through retrospective photogrammetry, aspects of the site have been able to be recreated and can be re-examined from perspectives that were not initially recorded.

Omega House

Omega House is a Roman villa built in the fourth century A.D. and modified through the sixth century A.D. The building is thought to be the home of the last school of philosophy in ancient Greece (Camp 1989). The structure was excavated in the late 1960's and early 1970's by John Camp. The site is not currently accessible and some aspects are backfilled or deteriorating due to exposure. There is a desire in the Hellenic Ministry of Culture and Sports to conserve and restore Omega house which has significant water features, mosaics and architecture. With that aim in mind, Omega House was modelled three dimensionally in its current state as well as being modelled using archival photographs taken when it was first excavated (Wallace et al 2017). The resulting models are being used to determine both the level of deterioration and the viability of restoration. In this case, with detailed modelling we are able to examine individual walls and work with engineers to move forward in the preservation of this important historic site.

These two examples show that there are considerable differences in what they end user's expectations and uses are for the photogrammetric models. What the end user needs depending on which of these purpos-

Figure 2. ountain of the Lamps 3D modelling as it was in 1972

es is intended, determines the photogrammetrist's approach to the modeling and in their assessment of available materials and whether those goals can be achieved.

Currently it is acknowledged that having a photogrammetric record of a site, monument or excavation is of great importance (Ragia and Moullou 2023). More site permits, in Greece for example, are now requiring such documentation. One result is that each of these projects benefits from having an infinite number of measurements and images available through the photogrammetric 3D models produced.

Previous, much older archaeological projects did not benefit from such technology and so have a finite number of records in their data sets. Metric data have been collected for CH documentation using digital photogrammetry and laser scanning methods and techniques, since the 1990s (Adel Haddad 2013). Through retrospective photogrammetry we are able to expand those analogue data sets to a level almost comparable to if those sites were excavated today.

Where retrospective photogrammetry comes into its element is when there has been significant deterioration since the time of excavation which can include destruction due to natural disasters, erosion, pillaging, encroachment of wildlife and plant life or even backfilling and removal of features in rescue archaeology (when a road or other civic project takes precedent).

What the previous examples illustrate is that the needs of the end user can be quite varied and that there needs to be a commnuncation between the photogrammetrist and the end user to determine that the outcome is the most productive and useable.

Figure 3. Omega house modelled from 1972 photographs

What the Photogrammetrist Needs

Access

One of the most difficult steps in the whole retrospective photogrammetry process is in ascertaining what photographs actually exist of a site and in what ways can they be accessed. While an official archive such

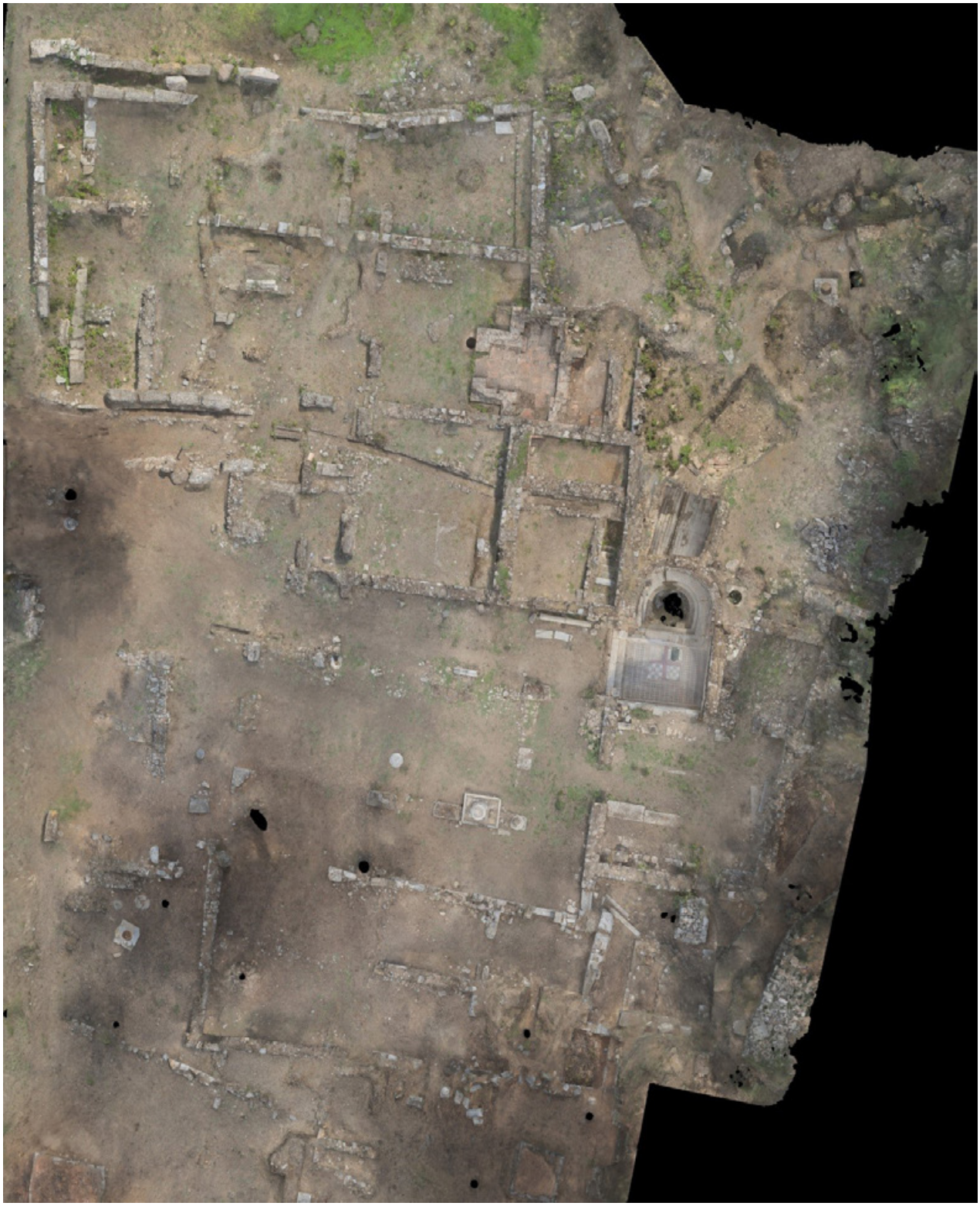

Figure 4. Omega House as modelled in 2017

as that of the American School of Classical Studies in Athens can be accessible online, one of the first problems to be encountered is data entry and organization. For example, a particular structure may be recorded with one name but as excavation continues that name may change. In order for the database to be able to access the right records in notebooks, the original name remains with the earlier records so in

order to search for the entire listing of photos, all of those names need to be known. For example, Omega House in the Athenian Agora can also be found as Roman House H, House C and Philosophical School C.

What is needed for a viable selection of photographs? As with any photogrammetry, a comprehensive collection of photographs with a suitable overlap between them is desired. The impediment to this is that we cannot go back in time and take missing pictures, also in cases where no significant changes have taken place over time, modern photographs, treated suitably can be added. Depending on the end user's needs, a site without full comprehensive coverage might work (Wallace et al. 2017).

Once an eligible collection of photographs has been identified, there is the matter of access. While many photographs are available through online archives, determining what else is available is vital. Accessing and scanning original negatives (film or glass) reduces errors considerably by removing the lens error of the enlarger lens, removing extra grain in prints and making sure that scans are done at a high resolution using the same scanner (and thus the same scanner lens). Our work has concentrated on reducing all aspects of error in this process (Wallace 2022).

What the End User Needs

In an archaeological project, the end user is not only the archaeologist. Since it is an interdisciplinary project, it involves researchers of almost all fields: archaeologists, architects, civil engineers, surveyors, specialists in photogrammetry, chemical engineers, conservators etc). Therefore the end product must meet the needs of all the scholars involved.

The end user needs an accurate textured model. There are two forms of accuracy. An aesthetic accuracy that can be presented to the public, and metric accuracy to be used in scholarly research, conservation, and restoration.

Aesthetic accuracy means that the retrospective model presented is convincing in its appearance in what it represents of the site as it was previously. This can, on paper, be a paradox because a visually accurate model can have a large metric error in its points and pixels. Agisoft Photoscan, the author's software choice due to its ability to process uncalibrated photographs, assigns accuracy results but those results are a comparison of what the end result is and what the software expected. The only true way to measure accuracy in a model is to take known, real life measurements and then take those same measurements within the model. In the case of Omega House in the Athenian Agora, measurements of distances of thirty to forty metres vary between reality and model at 20 to 30 centimeters error. Given that the resolution and ability to pinpoint measuring points constitutes at least that much difference the accuracy of the modeling is acceptable (Wallace et al. 2017, Panagiotopoulou et al. 2023).

The idea that photogrammetry could be used to attain accurate measurements that could be used for archaeological restoration is not new. In 1961 E.H.Thompson, writing about the restoration of Castle Howard noted that "Important monuments have been damaged in the past and restored or even entirely reconstructed with the help of photographs not taken for photogrammetric purposes." (Thompson 1961). Granted, these "reconstructions" were essentially ascertaining the measurements and locations of two dimensional elements but they support a longstanding idea that there is significant stored data in archival photographs. The photographs in the case of Castle Howard were taken in the 1920's and 1940's.

For the aesthetic modeling, end users lean towards smaller file sizes and the ability to present on multiple platforms and with limited equipment abilities and storage. Budgetary constraints and existing equipment abilities need to be taken into account and planned for by the photogrammetrist at this stage or the result can become unwieldy and unusable for the end user. For example, end products intended for the Hellenic Ministry of Culture and Sports, depending on the facility or subgroup, can be limited by existing resources as a result of budgetary constraints. The resulting product must be suitably scaled with regard the abilities of the existing infrastructure. For example, on slower machines, attempting to present the model to the client using Adobe 3D PDF or even the native environment in Agisoft Photoscan on a slower machine can result in jerky motion or the inability to present the object impressively. Viewer such as open 3D model viewer and Microsoft Mixed reality viewer can allow an impressive and flexible display of the model. For presentation to the public, Sketchfab allows a versatile and easily accessible means of sharing results with the non acedemics.

For Virtual Reality presentation purposes it is best to establish a budget beforehand and tailor the modeling /VR environment to suit the budgetary constraints of the client. Spatial constraints must also be considered when choosing the means by which the VR is to be presented. In some cases due to publishing rights, etc., the client may wish the VR to be only available on site. In these situations the number of viewers at one time can also be a consideration. In other cases the client may want their VR environment to reach the largest possible audience and choose online availability to do so.

For the geometric documentation of monuments and sites high accuracy and large scale end products are needed. However, this does not guarantee that everyone involved will be able to use it (Moullou and Mavromati 2007). The final output must have all necessary information to avoid misinterpretation. This is why the end product must be explicitly determined a priori, based on strictly defined needs, specified together by the end users and the photogrammetrist.

Drawings done on a site in the past, while attempting to be as objective as possible, are recorded with the subjective eye. Nuances that may have seemed important at the time can be over concentrated on while other less interesting aspects can be underrepresented (Wallace 2017). Retrospective photogrammetry can allow the contemporary researcher to re-examine those nuances and produce new more objective data.

Conclusions

Photogrammetric documentation of archaeological sites has rapidly and thankfully accelerated in recent years. When such documentation first became available in an affordable manner, many in the archaeological community were excited that it could be done but fewer questioned what could be done with it. For some of them an amusing model was created and was tucked away when it came to publications, apart from some screen shots. However, those who have come to understand the true potential of the technology have realized the amount of deep data that the models can provide for scholars to examine and quantify elements within the models.

Beyond the micro-examination of models, the amount of contained data within modelling has been realized by those focused on entire sites or monuments. The reconstruction of Notre Dame, Paris in as close to its original form would not be possible without the efforts of 3D modellers, not only for identifying the form of the original construction but also for test fitting elements before physical reconstruction (De Luca 2020)..

The ability to capture sites and monuments as they currently are or, within the context of this paper, as they were when first photographed, allows us to revisit and even reconstruct these aspects of cultural heritage with confidence and relative accuracy.

The effective completion of this effort is impossible without the creative collaboration of experts from various disciplines of study. The attempt to create a successful photogrammetric model, which is directly dependent on the use of the final product, necessitates rigorous preparation, research, and a lengthy collaborative effort of all relevant specialties.

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