DIGITAL SURVEY/3D DIGITALIZATION

3D archaeological field recording in Ostia

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Developments of 3D acquisition technologies such Structure-from-Motion (SfM) or LiDAR have led to a recording revolution, as these methods are increasingly applied to field archaeology. In recent years SfM (essentially digital photogrammetry) became a very relevant tool to manage and record 3D information in archaeological sites [Alamouri *et al.*, 2010].

3D methods are today an essential part of the archaeological toolkit. Together with classical documentation methods like photography, hand-drawn plans and profiles, SfM provides an additional technical method of documentation, which produces high quality data that can also be revisited during post excavation examination. These methods allow accurate and precise recording with a relative minimum of field time. Also, the quality of digital photography has increased in recent years, as the technical equipment of better quality became more affordable. The potential to create photorealistic and spatially accurate representations of objects or areas of interest has opened up new horizons in 3D recording [Guidi *et al.*, 2009] and archaeological projects have made increasing efforts [Ortiz Sanz *et al.*, 2010; Al-Kheder *et al.*, 2010; Olson *et al.*, 2013; Verhoeven *et al.*, 2011].

The advantages of SfM for research as well as its technical issues have been widely discussed by researchers from different disciplines [e.g. Green *et al.*, 2014; Chiabrando *et al.*, 2015; Benavides Lopez *et al.*, 2016; König *et al.*, 2016, Leier *et al.*, 2017].

In the usage of tablets and even smart phones interesting applications result iDig by Bruce Hartzler[1] like recently also Noel Hidalgo Tan from the Australian National University. Both are showing the potential even in the usage of tablets to record on field[2]. In particular *iDig*[3] can help to record excavation data more easily and accurately[4]. In most cases the best method for documenting is the combination of different techniques.

3D acquisition in situ

Normally in an archaeological excavation different types of information are produced in a relatively short amount of time. Recording of the *status quo* before an excavation goes on is essential. The objects are lying in situ and have to be documented in varying light conditions. Therefore, it is necessary to find an appropriate method and settings.

In 2016 and 2017 we used Agisosft PhotoScan[5] software, which is a reliable and affordable tool especially for archaeological fieldwork and post excavation examination, well known for its accuracy and easy access [Green *et al.*,

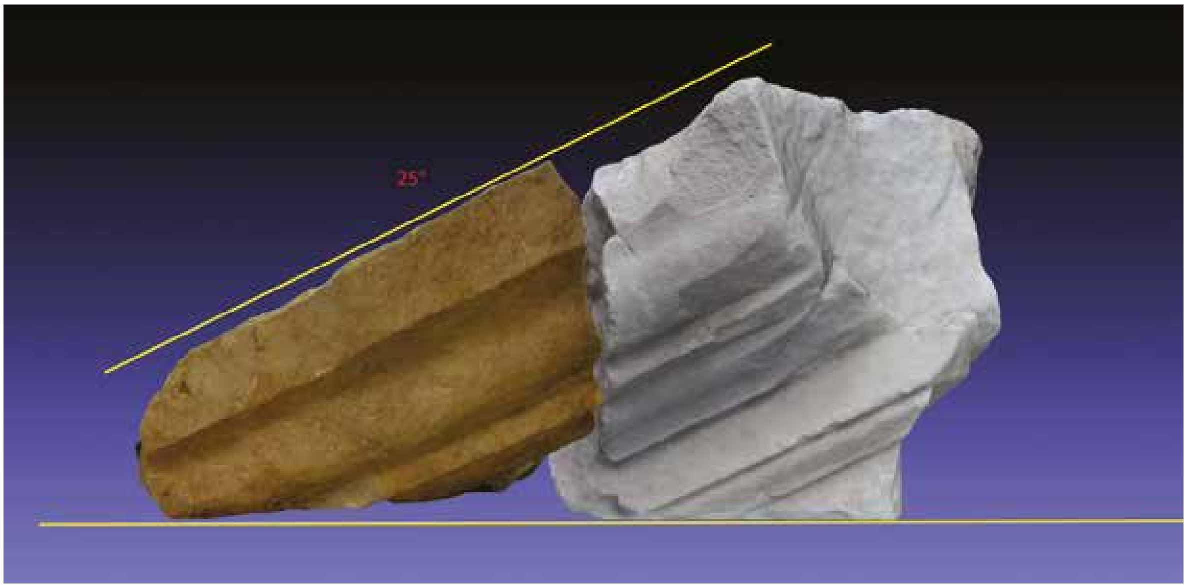

Fig. 1. Two 3D models of marble fragments reunited in MeshLab. *Source Axel Gering.*

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2014; Benavides Lopez *et al.*, 2016: 496; Koenig *et al.*, 2016: 28]. It is used to document the progress of the excavation and to record each archaeological evidence ("context") individually. In both campaigns Canon, Sony and Nikon digital cameras, iPad Pro 12.9-inch and a Tripod 360°[6] have been our photographic devices, as well as aerial photography with a Phantom III-Professional drone. For different material and purposes (from small finds to huge buildings) we adopted several methods/ approaches to our needs with a maximum of flexibility.

Method

The advantages of photogrammetry can be summarized as follows: low-cost and portable equipment, easy and fast in creating an archive for future needs, providing 3D models from small objects to large complex objects such as archaeological site, high accuracy depending on the needs of the project, providing metric and vector data of the texture of the object due to its image-based nature [Hassani, 2015]. These methods were applied to the Forum of Ostia by the Ostia Forum Project since 2010 [Gering, 2011; 2014; 2017]. Below we illustrate the different methodologies and approaches used by the OFP team.

Recording small finds and marble fragments with Canon camera

The number of photographs needed depends on the features of the block, e.g. finely carved ornamental features need additional photographs to be taken from various angles. Light conditions are a very important factor while recording the photographs to create and texture 3D models of high quality, especially in an outdoor environment. It is necessary that the photographs show as little shadowed parts as possible in order to avoid gaps in the mesh.

Given that the camera settings, in this case a standard DSLR camera Canon EOS 550D with a standard lens used, are adjusted to the light conditions, the object can be recorded within 5 to 10 minutes. It is advisable to keep the same settings for the lens (in this case 32 mm) and not to use varying zoom settings. Recording an object with the same settings makes it easier for the SfM technique to identify corresponding points in order to connect specific features on the surface of the object and generate an accurate dense point cloud. Each block is documented in two steps. After a first documentation with 30-40 pictures (fig. 1), the block is rotated by 90° and the documentation has to be repeated. For both recorded views a separate dense point cloud will be generated in PhotoScan. After masking the object, both views (or chunks) can be merged (in the menu workflow 'Merge chunks') by using markers. A full 3D model of high quality can be calculated out of 60 to 80 photographs altogether, with an average size of 5000000 faces.

iPad Pro 12.9-inch to support archaeological fieldwork

Mobile computing (tablets and even smart phones) is becoming more and more widespread. These devices have an integrated camera. The quality of the camera is still less than a dedicated device, but they have computational power and storage to process the images, and do other computational tasks. This makes them interesting to collect, map and archive information also in archaeological research. One can combine GPS, mapping, software for databases and other tasks. A new approach to conducting archaeological research is revolutionizing methods of recording history [Berggren *et al.*, 2015].

The simple convenience of eliminating extraneous equipment, displaying maps, or taking quick notes are several advantages, available of quick on-the-fly entry of digital information in a database, this helps to eliminate errors commonly encountered during the transfer of information from paper forms to a digital database. The disadvantages of tablet computers in the field is normally that the glare or reflection in the screen that can become invisible in direct sunlight. Several types of proprietary anti-glare (and screen protector) kits are available.

In 2016, the iPad Pro 12.9-inch was introduced as an on-site digital experiment to collect photo of recording every phase of excavation and to create 3D models. The results have showed that the iPad can be an ideal tool for field archaeology. Different applications can be interconnected on the iPad, some general purpose applications like Pixelmator or Filemaker.

In particular the photo quality achieved with the tablet's onboard camera proved more than sufficient for documenting both the terrain features under investigation and most of the archaeologically relevant material that team members located within that terrain. As in excavation contexts, wherever we required highly detailed photographic records to document important sites, a high-quality digital camera was also available. In Ostia it has provided an excellent covering of the object or context (100-150 snapshots) with high detail and in less time[7] to create 3D models (fig. 2)[8]. These high-resolution images can bring out details not visible to the naked eye, allowing scientists to study them much more closely [Pecchioli, 2018]. The tablet has a high quality and high resolution display, that has been very useful to immediately review the images, and see details in them that are cumbersome to see in a digital camera, or even on a computer.

The results after the campaign show to be a good tool for recording, of course its usefulness is not universal[9]. Some experience with the technology, or other digital cameras is needed, in order to optimize methods and approaches on site, where the information is unique and requires precision and knowledge of the means available [Pecchioli *et al.*, 2009].

Recording larger surfaces with Sony cameras

The main part of marble and ceramic objects in 2017 was recorded with Sony cyber shot RX100 mark I and mark III. The Sony mark remains our favourite camera for every-day 3D photo taking, producing excellent photos with 28 mm in the advanced automatic mode. The room TFR_2, which was the focus of the work in the seasons 2016 and

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Fig. 2. 3D model of surface structures of a closed archaeological context (2016). *Source http://ostiaforumproject.com/chapter-2-temple-votives-and-kitchen-gear-an-inventory-of-the-capitolium-cult-and-its-predecessors/*

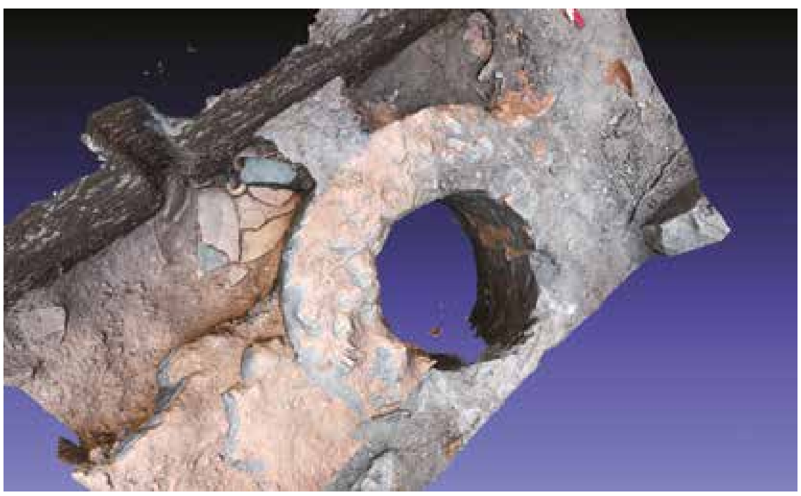
2017, has a surface of roughly 25 square meters. The surrounding brick walls are 2-3 meters high. This gave us the opportunity to take photos also from about 4-5 meters above the ground level, not only from inside the room, where some supplementing detail-photos helped to avoid gaps in the model underneath the overlapping stones of the marble-deposit.

Recording buildings with Phantom III drone and supplementing ground-based photos

In 2016 Bendegúz Takáts from the Pázmany Péter Catholic University used for the documentation of the room's surfaces a Phantom III drone and its included camera.

Beside single objects and little but detailed 3D documentations of important single-contexts[10] the main focus was to document the several stages of the excavation of the room TFR_2 by overall models. Here we used a range from 300-350 pictures, aerial views and photographs taken additionally from inside the room to cover all complex details. In 2017, when almost all stones were removed, a flat surface had to be recorded. Most of the pictures were taken from all four sides above the walls, while only deeper trenches were photographed by walking inside the room. The excellent contrast quality of the Sony-sensor allowed to get all details even from above even in light conditions of the early evening, when no direct sunlight came into the room anymore. Using high quality for aligning and medium quality for the cloud-building, calculation time of the dense cloud still was 16 hours (with a quadcore i7 of 7th generation and 16 GB RAM). Several 3D-models of a superficial ceramic depot next to a well could be brought together with the same tags in one overall 3D-model with different colouring in MeshLab (fig. 3).

Fig. 3. Several 3D models of a building pit with a well and a superficial sacrificial deposit next to it. *Source Axel Gering.*



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Measuring points were taken in 2016 and 2017 by our Hungarian cooperation partners. Their TFR model, georeferenced by more than 36 measuring-points with Agisoft PhotoScan Professional, was the fundament to incorporate all further models of the room (for further stages of the ongoing excavations). The aim was to document every main step of the excavation in an overall 3D model at the end of every two or three working days, supplemented by detailed models of all important contexts. Based on an orthographic screenshot of the rooms surface, all context plans were drawn during and after the campaign 2017 (fig. 4).

The question remains: how to use 3D models for classical publishing? PhotoScan allows to capture and export views (as screenshot-jpg) also with a high resolution of 12000 pixels x ca. 6100 pixels. Taking the screenshots in the orthophoto-mode (no perspective for plan-drawing) directly from the Agisoft-project files guarantees no loss of quality which definitely cannot be avoided when exporting the model to object- or ply-files and using other programmes like MeshLab or Cloud Compare. Only the "original model" screenshots guarantee a sufficient resolution when these orthophotos were taken as background for drawing the plans with Photoshop and Adobe Illustrator 6.0.

Beside our recording of TFR_2 the main focus since 2016 was the complete documentation of all remains of the Temple of Roma and Augustus (TRA) in the south of the Forum (fig. 5). 699 aerial photographs were taken with RPAS recording WGS 84 coordinates with every picture using its on-board GPS receiver producing an average of 1609084 meters of total error. A real time kinematic GNSS Base was set over the geodesic point at the Capitolium. Six 12-bit A4 targets were placed on the temple's podium, measured by a Leica GS14 GNSS and CS15 Field controller. Out of six targets, the measurements proved to be accurate at five resulting in an average of 0.034691 meters total error, thus greatly improving the accuracy of the georeferencing.

699 photos were aligned with "High accuracy", the default 40000 Key point and 4000 Tie point limit, "Generic" and "Reference" preselections deselected. The targets used on field were identified by the software using the "Detect marker" command.

Results

Marble fragments can show some problems for 3D documentation linked to the light subsurface dispersion, although a robust challenge for the digital survey: almost all our marble fragments fortunately had a patina, problems with a glancing surface did only occur with one Egyptian object which was made from extremely polished black stone.

The model for the room TFR_2 was georeferenced, and all data are considered in Gering's orthophoto-based context-plan showing the sequence of several steps of our work emptying the marble-deposit. Ceramic- and marble-objects in 3D files are kept on three sets of external hard-disks for post-excavation-work. Sections for publications were drawn basing on the 3D models. An implementation of reduced 3D models for web-based access via our webpage[11] is planned.

The final orthomosaic of the temple TRA with 8217 x 9102 pixels with written alpha channels for further GIS and CAD use was used to be the background of the temple's reconstruction. Further 3D models of single finds provide the advantage of simple measuring, even if the desired object is almost out of reach or too high: In Pisa's main church, a side-door ("Porta Santa") was decorated still in the 11th century with *spolia* brought from Ostia. The orthophotos showed for the first time their exact measurements, an estimated intercolumnium of minimally 274 cm and with the fitting capital put on top a measured intercolumnium (fig. 6) of 10 Roman feet (296.4 cm).

By projecting the podium underneath the plan also several mistakes which had occurred during the building-process, could be seen clearly (different positions for the pronaos' columns which resemble a possible change of plan or architect and a deviation of 1.3° of the supporting wall underneath the west row of inner columns). Obviously, the building stood at least four centuries, so the podium's concrete vaulting underneath the inner columns has proofed to be sufficient even with this mistake. The exact measuring of more than 250 relevant finds so far (roughly 12000 marbles were systematically checked to find them [Gering, 2017]) attached in the plan allowed to reconstruct the illumination system of this temple which seems to be unique: small windows of 21 cm width open directly into the back-wall of the four niches of each longitudinal wall[12].

The architrave in Pisa recorded in 2018 forced us to reconsider our former reconstruction-hypothesis of five full columns inside the cella[13]. Thanks to the Pisa-evidence we can reconstruct now the only possible position of the cella-blocks underneath the niches. The result is quite surprising: the method of illuminating indirectly the statues in the niches of the temple's longitudinal walls does not have a correspondence before Antonine age, so this Augustean temple marks an important innovation in the history of architecture.

Still work in progress is the full reconstruction of the temple with sketch-up including its implemented possibilities of reconstructing the temple's inside-illumination according to different daytime and a data-base for all relevant fragments belonging to the actual temple-reconstruction[14].

Unfortunately, the future accessibility for 3D data is still unclear, the situation improved with open standards becoming more widely used, especially in mobile platforms, but it is still a complex issue. Text, html, and jpeg or png images are quite "future-proof", and preserving them is a good option at least for SfM to allow one to later recreate again a 3D model if the original one cannot be read anymore.

Fig. 4. 3D model of a room-surface immediately below a marble deposit with coloured contexts of several sacrificial deposits and votive pits. *Source Axel Gering*.

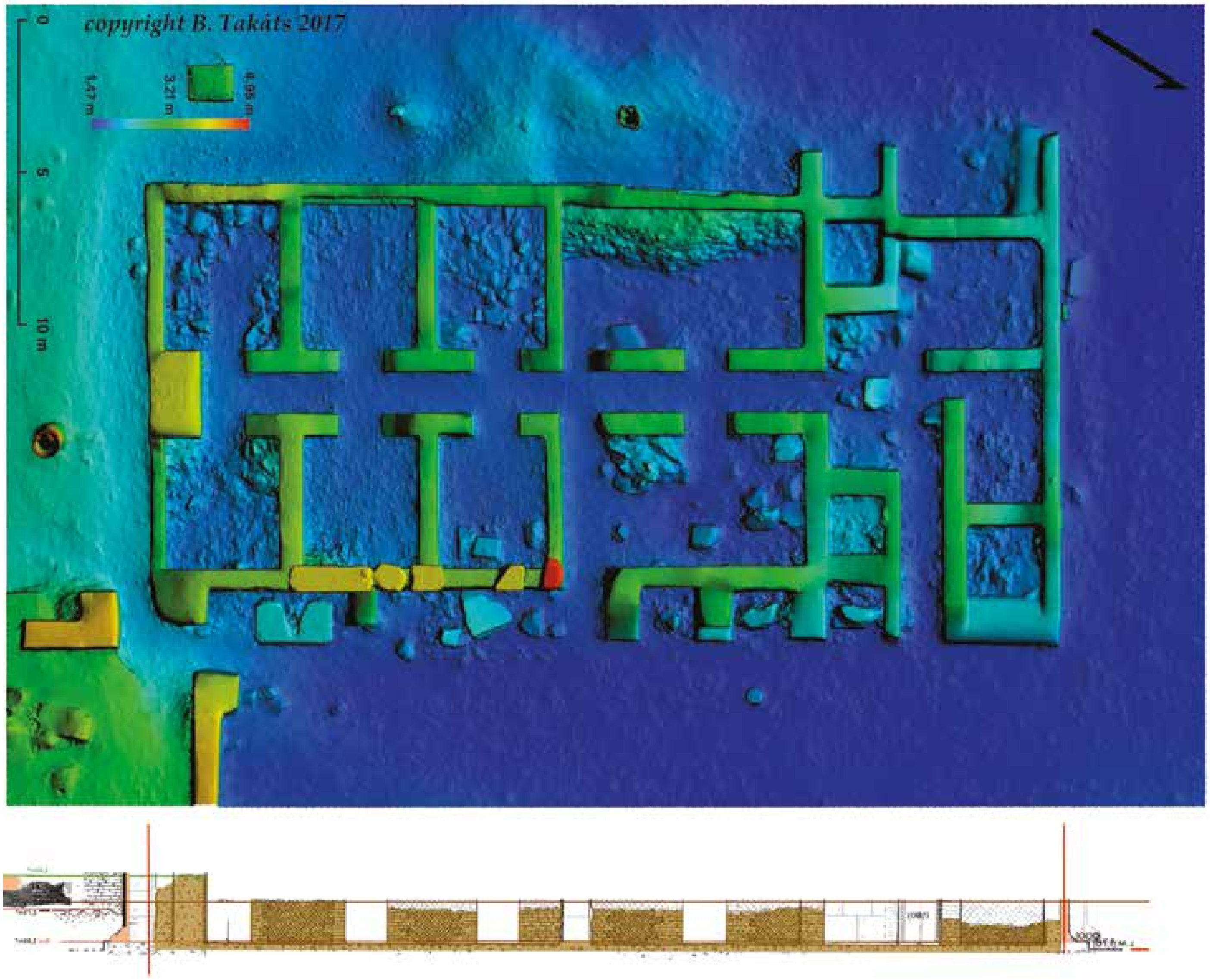

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Fig. 5. False coloured elevation model based on 3D model of a temple podium. *Source Bendegúz Takáts.*

Outlook: using URLs and QR-codes to identify objects

How can we identify documented fragments/evidence in the post-processing? We found our solution: labels with QR-code point to a unique webpage for each fragment.

This does not just give unique identifiers to the fragments, but does allow us to set up a web page to describe them. Furthermore, automatic analysis of the photo assigns them to "their" fragment. Images can be stored in fragment specific folders using this method.

Making the data available through the web also without plugins or javascript is probably one of the best ways to ensure future accessibility.

Conclusions

The different recording methods developed for the requirements of the Ostia Forum Project are promising in their flexibility and cost efficiency. Also, the standards for photogrammetric photography and basic camera settings were set for future campaigns. The results show the potential of the current generation of SfM technique and the accuracy in 3D documentation in situ.

Finally, the generated 3D models are convincing in their accuracy and also the appearance of the digitized architectural elements is satisfying. All plans were drawn based on the models.

The final results, edited and optimized in different solutions for multimedia presentation and prototyping were soon ready for further usage, like the implementation in the multimedia detail database.

NOTES

1. IT Specialist for the Agora Excavations in Athens; *http://agathe.gr/*.
2. Noel Hidalgo Tan has presented a paper at the Australian Archaeological Association on his use of tablets to record the location and motif details of rock art in Thailand: *http://www.southeastasianarchaeology.com/2011/12/07/ipad-record-rock-art/*.
3. *http://idig.tips/*.
4. *http://www.ascsa.edu.gr/index.php/news/newsDetails/bruce-on-idig*.
5. We used VisualSfM, MeshLab, CloudCompare and Photoshop, Cad software in post processing. We tested earlier different types of 3D acquisition methods: 123D Catch is a good free app that lets to create 3D scans of virtually any object, but in field it does not ensure complete coverage and has some offline mode problems. Sketchfab offers an efficient web-based platform for creating and sharing 3D content. Normally one can upload especially small objects: *http://*

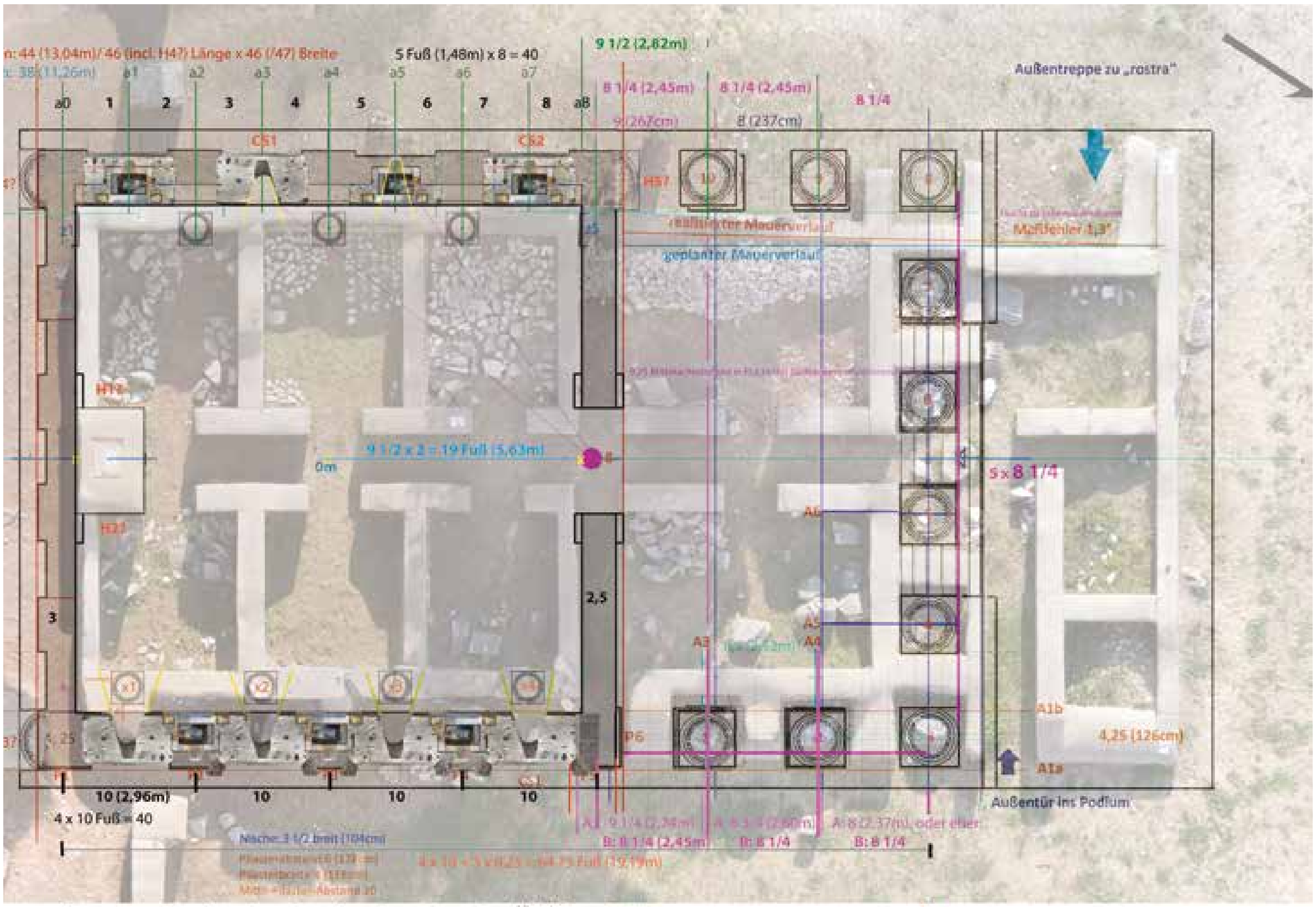

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Fig. 6. Reconstruction of the complete layout of a lost temple based on the 3D model of its podium remains and single marble fragments. *Source Axel Gering*.

www.hypergridbusiness.com/2016/08/sketchfab-offers-nearly-a-million-vr-models/.

6. In order to use this construction in wood, a relatively flat horizontal area is needed, but owing to its weight, a fast repositioning is no problem, also in case the light conditions change. The installation for the monopod provided the possibility to spin the camera around the object at a constant height and distance, while the object was centered. Also, the camera could easily be moved up and down to get photographs from top or bottom angles. However, because of its light-weighed construction this framework was not solid enough to carry architectural elements larger than 30 x 20 x 20 cm. While moving the camera around the object, every 20 to 22 degrees a shot was made with the whole object in focus, getting 48 pictures of one view (realized by Fawzi Mohamed and Laura Pecchioli).

7. *https://rangitotoarchaeology14.wordpress.com/tag/ipad-archaeology/.*

8. As frequently found in temple-contexts of the whole Graeco-Roman world, these lits once covered little ceramic bowls in which the meat of the sacrificed animals could have been served to the spectators. So, it is hardly another coincidence that we have found in one room-corner a surface of a bone-deposit, which seems to have consisted of several big bones of bulls, maybe even with cutting-marks on the bones themselves. Due to reasons of conservation after fotographing we left the bones covered in their original context waiting for further specialized analysis.

9. *http://arch-pad.blogspot.de/2012/.*

10. See Pecchioli's contribution to context "Method" and others.

11. *http://ostiaforumproject.com/.*

12. Compare the contribution of Daniel Damgaard in this volume: the possibilities of further illumination of the roof is dicussed there.

13. East longitudinal wall.

14. *Idem* in note 9.

ACKNOWLEDGEMENTS

Thanks to the courtesy and hospitality of the directors of the "Scavi di Ostia", Angelo Pellegrino, Cinzia Morelli and Mariarosaria Barbera, and the Superintendence of Rome and Ostia we had the chance since years to work up all material from old and recent excavations regarding the Forum. We like to thank Paola Germoni and the Humboldt-University-team too and our Hungarian colleagues: thanks to Gabor Bertok, Zsolt Wagner, Bendegúz, Zsombor, Fawzi Mohamed (Fritz Haber Institute, Berlin) and all other members of the team: http://www.ostiaforumproject.com; http://www.iovia.eu.

BIBLIOGRAPHY

Alamouri A., Pecchioli L., *ISEE: retrieving information navigating in the historical Baalbek*, in *ISPRS Proceedings of the 5th 3D GeoInfo Conference*, 2010: 81-85.

Al-Kheder S., Al-shawabke Y., Haala N., *Developing a documentation system for desert palaces in Jordan using 3D scanning and digital photogrammetry*, "Journal of Archaeological Science", 36, 2009: 537-546.

Benavides López J.A., Aranda Jiménez G., Sánchez Romero M., Alarcón García E., Fernández Martín S., Lozano Medina A., Esquivel Guerrero J.A., *3D modelling in archaeology: the application of Structure-from-Motion methods to the study of the megalithic necropolis of Panoria (Granada, Spain)*, "Journal of Archaeological Science: Reports", 10, 2016: 495-506.

Berggren Å., Dell'Unto N., Forte M., Haddow S., Hodder I., Issavi J., Lercari N., Mazzuccato C., Mickel A., Taylor J., *Revisiting reflexive archaeology at Çatalhöyük: integrating digital and 3D technologies at the trowel's edge*, "Antiquity", 89/344, 2015: 433-448.

Chiabrando F., Donadio E., Rinaudo F., *SfM for orthophoto generation: a winning approach for cultural heritage knowledge*, "The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences", XL/5(W7), 2015: 91-98.

Gering A., *Das Stadtzentrum von Ostia in der Spätantike. Vorbericht zu den Ausgrabungen 2008-2011*, "Römische Mitteilungen", 117, 2011: 409-509.

Gering A., *Marble recycling-workshops nearby the Temple of Roma and Augustus: an interim report of the Ostia-Forum-Project's working campaigns in 2013 and 2014*, in De Ryut C., Morard T., Van Haeperen F. (éd. par), *Nouvelles études et recherches sur les quartiers occidentaux de la cité*, Actes du colloque international, 2014: 23-30.

Gering A., *Marmordepots. Zum "Recycling" des Forums von Ostia im 5. Und 6. Jh. n. Chr.*, in Kurapkat D., Wulf-Rheidt U. (hrsg. von), *Werkspuren. Materialverarbeitung und handwerkliches Wissen im antiken Bauwesen*, Regensburg, 2017: 149-166.

Green S., Bevan A., Shapland M., *A comparative assessment of Structure-from-Motion methods for archaeological research*, "Journal of Archaeological Science", 46/1, 2014: 173-181.

Guidi G., Remondino F., Russo M., Menna F., Rizzi A., Ercoli E., *A multi-resolution methodology for the 3D modelling of large and complex archaeological areas*, "Special Issue in International Journal of Architectural Computing (IJAC)", 7/1, 2009: 39-55.

Hassani F., *Documentation of cultural heritage; techniques, potentials, and constraints*, "The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences", XL/5(W7), 2015: 207-214.

Koenig C.W., Willis M.D., Black S.L., Castañeda A.M., *Archaeological 3D mapping: the Structure-from-Motion revolution*, "Journal of Texas Archeaology and History", 3, 2016: 1-36.

Leier A.L., Chesley J.T., White S., Torres R., *Using unmanned aerial vehicles and Structure-from-Motion photogrammetry to characterize sedimentary outcrops: an example from the Morrison Formation*, "Sedimentary Geology", 354, 2017: 1-8.

Olson B.R., Placchetti, R., Quartermaine J., Killebrew A.E., *The Tel Akko Total Archaeology Project (Akko, Israel): assessing the suitability of multi-scale 3D field recording in archaeology*, "Journal of Field Archaeology", 38/3, 2013: 244-262.

Ortiz Sanz J., de la Luz Gil Docampo M., Martinez Rodriguez S., Rergo Sanmartin M.T., Mejide Cameselle G., *A simple methodology for recording petroglyphs using low-cost digital image correlation photogrammetry and consumer-grade digital cameras*, "Journal of Archaeological Science", 37/12, 2010: 3158–3169.

Pecchioli L., Mohamed F., Carrozzino M., *ISEE: retrieving information in cultural heritage navigating in 3D environment*, in Bock H.G., Jäger W., Winckler M.J. (eds. by), *Proceedings of the SCCH 2009: Scientific Computing and Cultural Heritage, Contributions in Computational Humanities*, 2009: 157-165.

Pecchioli L., *3D application in archaeoseismology*, in *Antiker Bauschmuck aus Terrakotta: Work in Progress. Ein Symposium der Humboldt-Universitäts-Gesellschaft (HUG)*, 2018: in press.

Verhoeven G., *Taking computer vision aloft: archaeological three-dimensional reconstructions from aerial photographs with PhotoScan*, "Archaeological Prospection", 18, 2011: 67-73.

ABSTRACT

3D ARCHAEOLOGICAL FIELD RECORDING IN OSTIA ANTICA

Since 2010, the Ostia Forum Project of the Humboldt-University of Berlin (Winckelmann-Institute) involves 3D documentation methods. In 2010 we cooperated with the German Aerospace (DLR), in 2011 with TOPOI Berlin (*https://www.topoi.org/home/about-topoi/*) using laser scanners. Since 2012 photogrammetry became more accessible and efficient every year so we tried it on our own, and since 2015 with the help of our new Hungarian cooperation partners from Pázmany Péter Catholic University at Budapest. This article lines out our actual 3D work and digital workflow during the archaeological campaigns 2016 and 2017 in Ostia Antica, starting from modelling small finds, archaeological contexts and catalogue with QR-codes to rooms, buildings and the whole site.

DOCUMENTAZIONE 3D IN SITU A OSTIA

Dal 2010, l'Ostia Forum Project dell'Università Humboldt di Berlino (Winckelmann-Institute) prevede metodi di documentazione 3D. Nel 2010 abbiamo collaborato con il Centro Aerospaziale Tedesco (DLR), nel 2011 con TOPOI Berlin (https://www.topoi.org/home/about-topoi/) utilizzando scanner laser. Dal 2012 la fotogrammetria è diventata più accessibile ed efficiente ogni anno, di conseguenza l'abbiamo impiegata e, dal 2015, con l'assistenza dei nostri nuovi partner di cooperazione ungheresi dell'Università Cattolica Pázmany Péter di Budapest. Questo articolo illustra il nostro attuale lavoro 3D e il flusso di lavoro digitale durante le campagne archeologiche del 2016 e del 2017 a Ostia, partendo dalla modellazione di piccoli reperti, contesti archeologici e dal catalogo con QR-codes per ambienti, edifici e per l'intero sito.

KEYWORDS

3D acquisition, Structure-from-Motion, PhotoScan, Ostia, QR-code, URLs, iPad

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