A new Approach for Structure from Motion Underwater Pile-Field Documentation

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Introduction

In this poster, we present a new reproducible underwater SfM-documentation workflow which was established for a project on the pile-dwelling site «Ploča, Mičov Grad» in Lake Ohrid, Republic of Macedonia.

A Swiss-Macedonian team conducted in summer 2018 a surface analysis of the site with the aim of providing the first coherent absolute chronological dates of the site. A section of 40 m² was mapped and 268 piles were sampled. The samples, dated by a combination of dendrochronology and radiocarbon dating, prove settling activities around 1200 BC, around 1900–1800 BC and around 4500–4300 BC.

Video: Fieldwork impressions

Dendrochronological sampling requires cutting the top-ends of the piles and thus changes the preserved situation. Beforehand documentation must ensure that every pile is distinctly labeled and the location of each pile is accurately captured. While on land, this can easily be achieved, underwater working conditions complicate common procedures, e.g. mapping each pile with a theodolite and prism pole will get difficult and inefficient.

Instead, we developed a new workflow for Structure from Motion (SfM)[3] based underwater documentation. Our approach is time-saving, accurate, yet inexpensive. SfM is already widely used in underwater archaeology for the documentation of shipwrecks[4]. Also, some initial tests had already been done on pile dwelling sites[5].

Structure from Motion based Documentation Workflow

The on-site workflow:

1) An area of 10 m by 10 m was set up with ropes and measuring tapes using wooden posts as corners and reference of the local grid. We worked on slices of 10 m² (10 m x 1 m) at a time.
2) The area was cleaned from macrophytes and the covering sediments.
3) The piles were labeled with an individual number (**fig. 1, 2**).
4) A coded marker was fixed on each axis every meter for geo-referencing. For each coded marker, the altitude was calculated using the water depth and the water level.
5) The area was photographed from both sides 1–1.5 m above the lake bottom ensuring a continuous overlap of at least 60 % in each picture (two or four markers had to be visible on the photos). About 60 photos were taken for a slice of 10 m².
6) Before the piles could be sampled a preliminary 3D-model of the documented area had to be evaluated. In case of errors or gaps, the photographs could be newly taken before the situation on the site had been irreversibly changed.

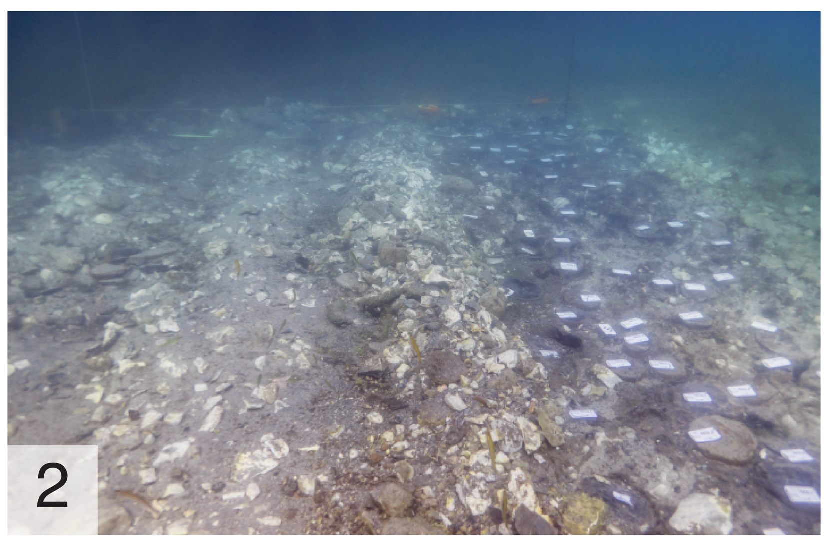
This procedure (1–6) was repeated for all four sections of 10 m², whereas the removed sediment of a newly opened section was used as the cover of the already sampled one (**fig. 2**).

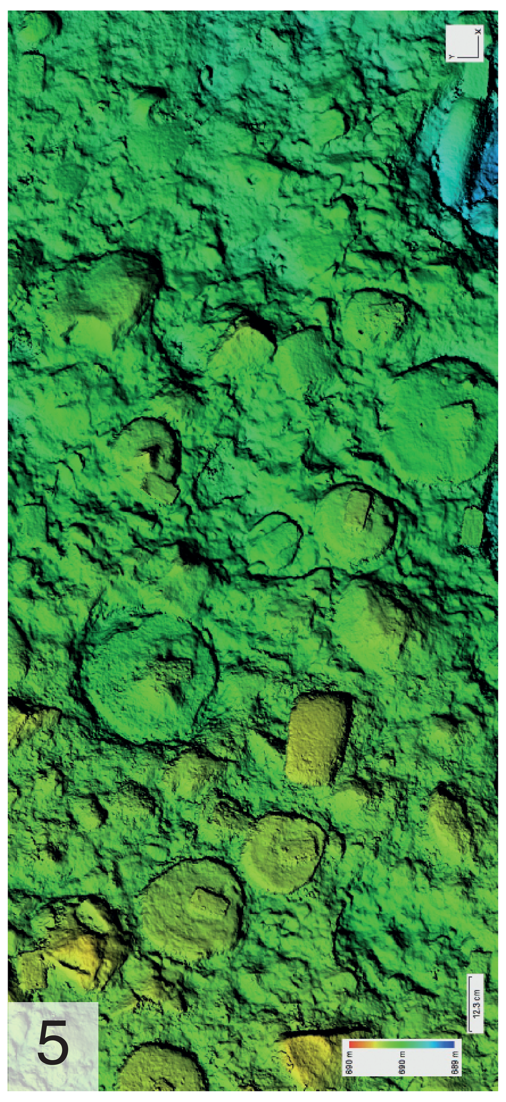
Lastly, the corner posts were measured in with an RTK-GNSS receiver mounted onto a buoy held and maneuvered by the diver with a rope.

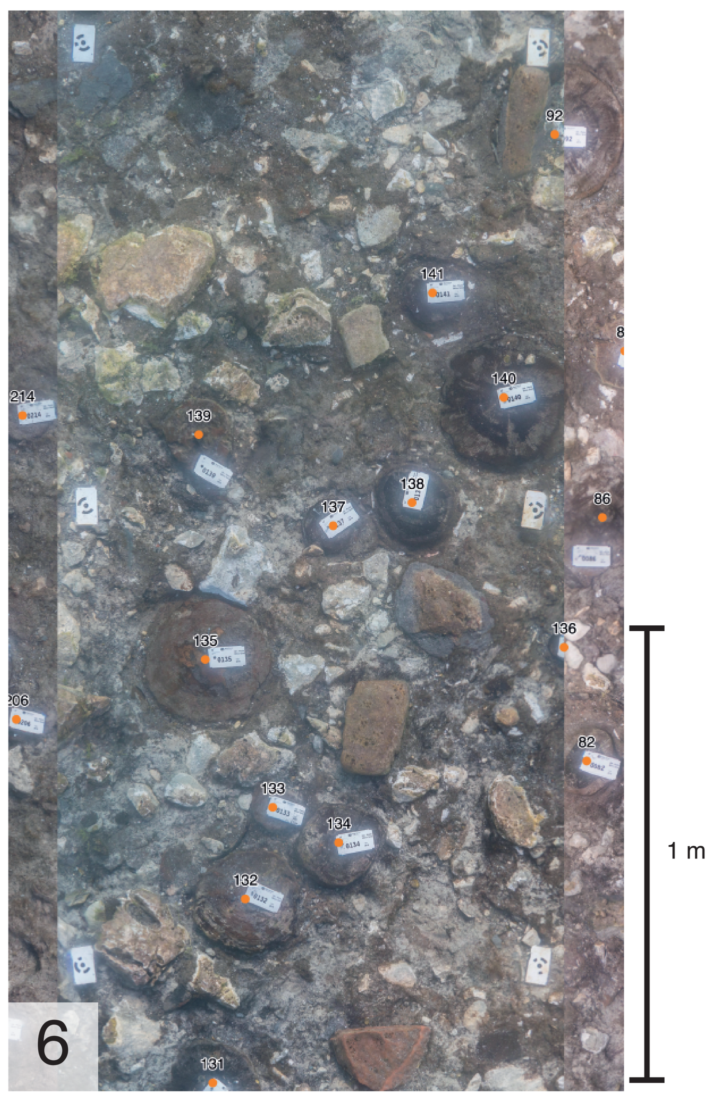
The post-processing workflow:

1) The post-processing workflow was developed with high-quality settings in Agisoft PhotoScan and applied to all four models (**fig. 3–5**).[6]
2) The exported GeoTIFFs were combined in QGIS and the central point of each pile was vectorized (**fig. 6, 7**).
3) An error evaluation was run in QGIS identifying deviations in the x- and y-coordinates to the ideal coordinates of the local grid. The mean absolute deviation of all 88 markers is 0.8 cm on the x- and 1.0 cm on the y-axis. This deviation consists of the internal error of the model and, more importantly, the inaccuracies from the setting up of the local grid on site.

The resulting map can be used for the analysis of patterns in the spatial distribution of the piles concerning e.g. their age, size or wood species. This will lead to answers regarding architecture, internal chronology, and in-site settlement dynamics.







Figures:

1: Final cleaning before photographing. Labels with pile-ID and coded markers are already in place.

2: Already documented and sampled area on the left is covered with the sediments of the not yet documented and sampled area on the right.

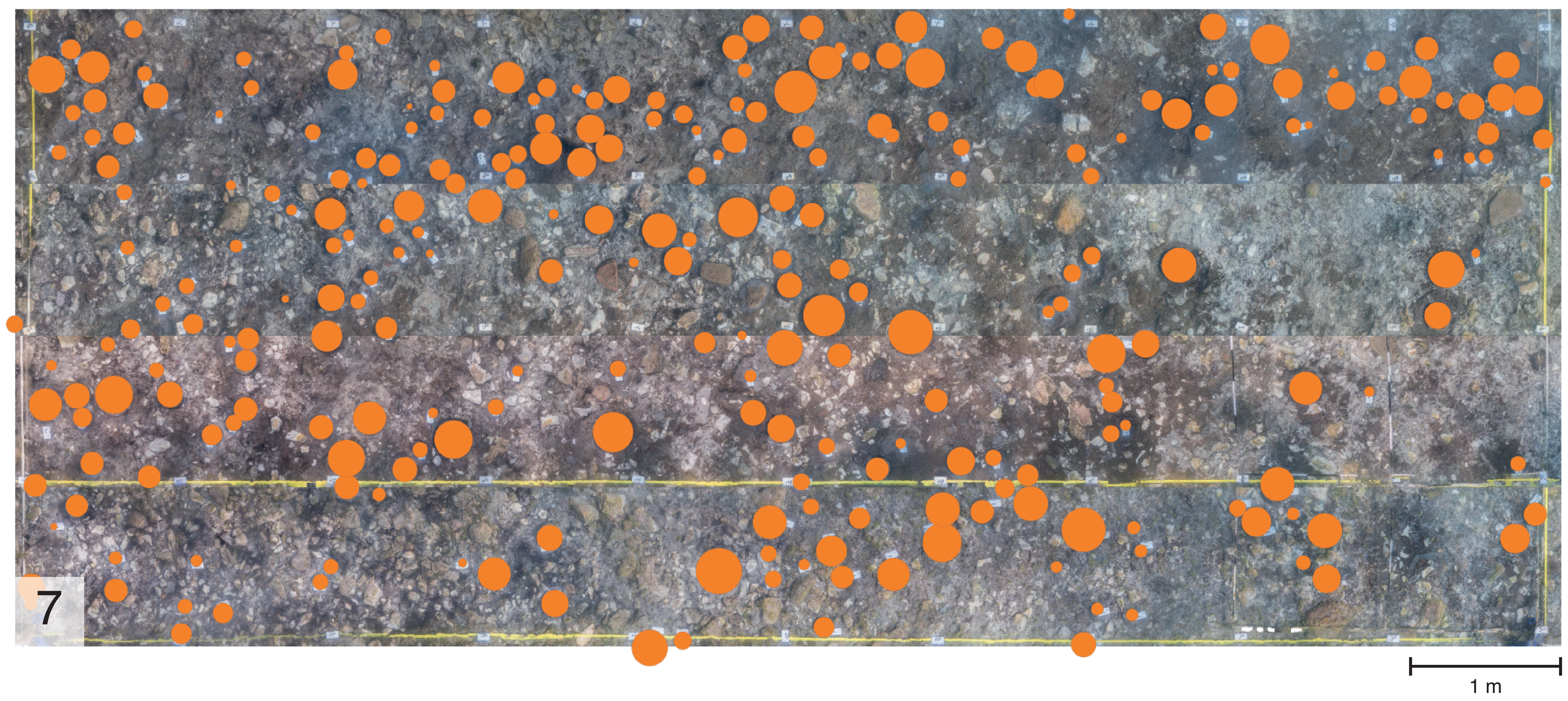
3: Sparse point cloud which orientates the different camera positions and a single photo accordingly positioned.

4: With the reconstructed camera positions a dense point cloud is generated through stereo-matching.

5: The dense point cloud is used to build a digital elevation model.

6: From the digital elevation model a georeferenced Orthomosaic is produced which is exported as GeoTIFF. In QGIS the location of each pile is vectorized and combined with the dendrochronological data for further analysis.

7: All 4 orthomosaics combined, covering the total sampled area of 40 m². Piles displayed according to their surface.



Limitations

1. Computational power: Most of the calculations are very hardware demanding. With a growing number of photos, calculation time will increase rapidly.

2. Photo Quality: The Photos are the only source for the reconstruction. Poor photo quality will lead to poor model quality.

3. Georeferencing: As our model is created with local excavation coordinates it has to be transformed into a geodetic coordinate system. Consequently, it is mandatory to measure in several points either with theodolite / total station or an RTK-GNSS receiver. Waves and currents will lead to deviations.

Conclusion

The presented method is highly promising for underwater-documentation of prehistoric pile-fields, yielding digital plans in an efficient, accurate and inexpensive way. Under the given conditions this workflow has proven its qualities.

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[3] Used Software: Agisoft PhotoScan Professional (1.4.4), since December 2018 Agisoft Metashape Professional (1.5), For technical terms: Agisoft LLC, Agisoft PhotoScan User Manual: Professional Edition, Version 1.4 (2018).

[4] K. Yamafune, Using Computer Vision Photogrammetry (Agisoft PhotoScan) to Record and Analyze Underwater Shipwreck Sites (Doctoral dissertation Texas A&M University 2016).

[5] M. Block/C. Dworsky/C. Löw/H. Seidl da Fonseca/B. Gehmlich/D. Wittchen/N. Görsch/P. Suchowska/B. Ducke, Underwater Videogrammetry with Adaptive Feature Detection at "See am Mondsee", Austria, Studies in Digital Heritage Vol. 1/2, 2017, 547–565.

[6] A paper with the detailed settings for each step is currently in preparation.

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