Peer Community In Archaeology

Beyond Deep Blue: Underwater robotics, simulations and archaeology

Daniel Carvalho *based on peer reviews by* ***Marco Moderato*** *and 1 anonymous reviewer*

Diamanti, Eleni; Yip, Mauhing; Stahl, Annette; Ødegård, Øyvind (2024) Advancing data quality of marine archaeological documentation using underwater robotics: from simulation environments to real-world scenarios. Zenodo, ver. 4, peer-reviewed and recommended by Peer Community in Archaeology.
https://doi.org/10.5281/zenodo.8305098

Submitted: 01 September 2023, Recommended: 02 January 2024

Cite this recommendation as:
Carvalho, D. (2023) Beyond Deep Blue: Underwater robotics, simulations and archaeology. *Peer Community in Archaeology*, 100402. 10.24072/pci.archaeo.100402

Published: 02 January 2024

Diamanti et al. (2024) is a significant contribution to the field of underwater robotics and their use in archaeology, with an innovative approach to some major problems in the deployment of said technologies. It identifies issues when it comes to approaching Underwater Cultural Heritage (UCH) sites and does so through an interest in the combination of data, maneuverability, and the interpretation provided by the instruments that archaeologists operate. The article's motives are clear: it is not enough to find the means to reach these sites, but rather is fundamental to take a step forward in methodology and how we can safeguard certain aspects of data recovery with robust mission planning.

To this end, the article does not fail to highlight previous contributions, in an intertwined web of references that demonstrate the marked evolution of the use of Unmanned Underwater Vehicles (UUVs), Remote Operated Vehicles (ROVs), Autonomous Underwater Vehicles (AUVs) and Autonomous Surface Vehicles (ASVs), which are growing exponentially in use (see Kapetanović et al. 2020). It should be emphasized that the notion of 'aquatic environment' used here is quite broad and is not limited to oceanic or maritime environments, which allows for a larger perspective on distinct technologies that proliferate in underwater archaeology. There is also a relevant discussion on the typologies of sensors and how these autonomous vehicles obtain their data, where are debated Inertial Measurement Units (IMU) and LiDAR systems.

Thus, the authors of this article propose the creation of a model that acquires data through simulations, which allows for a better understanding of what a real mission presupposes in the field. Their tripartite method - pre-mission planning; mission plan and post-mission plan - offers a performing algorithm that simplifies and provides reliability to all the parts of the intervention. The use of real cases to create simulation models allows

for a substantial approximation to common practice in underwater environments. And yet, the article is at its most innovative status when it combines all the elements it sets out to explore. It could simply focus on the methodological or planning component, on obtaining data, or on theoretical problems. But it goes further, which makes this approach more complete and of interest to the archaeological community. By not taking any part as isolated, the problems and possible solutions arising from the course of the mission are carried over from one parameter to another, where details are worked upon and efficiency goals are set.

One of the most significant cases is the tuning of ocean optics in aquatic environments according to the idiosyncracies of real cases (Diamanti et al. 2024: 8), a complex endeavor but absolutely necessary in order to increase the informative potential of the simulation. The exploration of various data capture models is also welcome, for the purposes of comparison and adaptation on a case-by-case basis. The brief theoretical reflection offered at the end of the article dwells in all these points and problematizes the difference between terrestrial and aquatic archaeology. In fact, the distinction does not only exist in the technical component, as although it draws in theoretical elements from archaeology that is carried out on land (see Krieger 2012 for this matter), the problems and interpretations are shaped by different factors and therefore become unique (Diamanti et al 2024: 15). The future, according to the authors, lies in increasing the autonomy of these vehicles so that the human element does not have to make decisions in a systematic way. It is in that note, and in order for that path to become closer to reality, that we strongly recommend this article for publication, in conjunction with the comments of the reviewers. We hope that its integrated approach, which brings together methods, theories and reflections, can become a broader modus operandi within the field of underwater robotics applied to archaeology.

References:

Diamanti, E., Yip, M., Stahl, A. and Ødegård, Ø. (2024). Advancing data quality of marine archaeological documentation using underwater robotics: from simulation environments to real-world scenarios, Zenodo, 8305098, ver. 4 peer-reviewed and recommended by Peer Community in Archaeology. https://doi.org/10.5281/zenodo.8305098

Kapetanović, N., Vasilijević, A., Nađ, Đ., Zubčić, K., and Mišković, N. (2020). Marine Robots Mapping the Present and the Past: Unraveling the Secrets of the Deep. Remote Sensing, 12(23), 3902. MDPI AG. http://dx.doi.org/10.3390/rs12233902

Krieger, W. H. (2012). Theory, Locality, and Methodology in Archaeology: Just Add Water? HOPOS: The Journal of the International Society for the History of Philosophy of Science, 2(2), 243–257. https://doi.org/10.1086/666956

Reviews

Evaluation round #1

DOI or URL of the preprint: https://doi.org/10.5281/zenodo.8306502
Version of the preprint: 2

Authors' reply, 19 December 2023

Dear Recommender and Reviewers,

We would like to thank you for taking the time to review our work. Your overall feedback has proven to be very constructive and significantly valuable. By carefully addressing each of your comments, we believe that we managed to enhance the quality of our paper. Attached you will find the list of the addressed comments

(our responses in italics), with reference to the updated manuscript's lines. We hope that you will find our revised manuscript worthy of recommendation.

On behalf of all co-authors,

Eleni Diamanti

Download author's reply

Decision by Daniel Carvalho, posted 30 October 2023, validated 30 October 2023

Dear authors,

After the review process has been completed, I am pleased to have read your article, which is also noticeable in the case of both reviewers. In order for the article to reach its full potential, some elements have been highlighted, with minor corrections and additions being requested. I believe that when these changes are made - and I would therefore ask you to pay attention to the reviewers' constructive comments - a new version of the article can be certainly be recommended.

Reviewed by Marco Moderato, 09 October 2023

Review of "Advancing data quality of marine archaeological documentation using underwater robotics: from simulation environments to real-world scenarios".

General overview

The paper presents a framework for the visual-based 3D documentation of underwater archaeological sites via marine robotic operations. The authors address the three main phases of an underwater robotic mission: the planning phase, the mission-time phase, and the offline processing one. The proposed techniques deal with multi-vision sensor configurations and underwater effects on images, and the real-time assessment of the acquired data, targeting the within-mission reconstruction of the site. The study contributes to the literature on the use of marine robotics in underwater archaeology and suggests new directions for future research in this field.The work by Diamanti, Yp, Stahl, and Ødegård is excellent. The paper presents a new non non-intrusive method for mapping underwater heritage.

Title/abstract/introduction

Does the title clearly reflect the content of the article? YES
Does the abstract present the supported findings of the study concerned and no other?YES
Does the introduction clearly explain the motivation for the study?YES
Is the research question/hypothesis/prediction clearly presented?YES
Does the introduction build on relevant recent and past research performed in the field?YES

Methods

Are the methods and analysis described in sufficient detail to allow replication by other researchers? YES

The explanation of the workflow is very detailed and clear. In the example provided the values for mimicking volumetric scattering are reported precisely; it would be interesting to have comparative data of different work contexts to understand how they affect the results of the elaboration. I appreciated the attention shown in reporting the accuracy issues and the way these have been integrated into the workflow.

Results

The results of the workflow are very promising. The quality of data that can be obtained and the clarity of the workflow can become an established protocol of fieldwork in underwater archaeology.

Discussion

The authors argue that archaeological fieldwork underwater is characterized by a focus on solving tasks through predetermined best practices and is distinct from analysis and interpretation, which are integrated elements

in archaeological workflows on land.
While I don't completely agree with this argument (underwater stratigraphic excavations while differing in actions implemented, maintain the general methodologic framework, i.e. Grado's shipwreck) it is true that underwater fieldwork activity requires specific workflows and can only benefit from the technological advances that are structurally incorporated in them.

Tables and figures

Fig. 1 (the Spatiotemporal graph) is in my opinion not clear, as the two bars are of the same dimension but different time scales (minutes-hours/ hours-days)

All the other images are excellent.

Reviewed by anonymous reviewer 1, 19 October 2023

Peer Review The paper titled "Advancing Data Quality of Marine Archaeological Documentation Using Underwater Robotics: From Simulation Environments to Real-World Scenarios" by Diamanti et al. is a well-crafted and in-depth exploration of an important topic in maritime archaeology, namely, the measurement and documentation of underwater cultural heritage. However, the paper could benefit from increased cohesion and unity: currently, it takes some time for the reader to discern the logical flow of the three stages, which appear somewhat disjointed. In principle, the data and ideas in the subdivisions "Planning a Mission," "Running a Mission," and "Processing a Mission" could each be expanded into smaller standalone papers. Nevertheless, this paper makes a valuable contribution to the field and is recommendable for publication, with the suggestion of minor additions and clarifications.

Title/Abstract/Introduction

The title and abstract reflect the article's content, but the abstract, in particular, should provide more direct references to the actual techniques and technologies employed, or at least mention them by name. The introduction effectively communicates the relevance and significance of the study within the context of Underwater Cultural Heritage (UCH) research. Both the introductory chapter and the abstract should more emphatically highlight the contributions and innovations presented in this paper.

State-of-the-Art in Marine Technology

The state-of-the-art section is concisely and clearly written, referencing an adequate number of recent publications while also providing a brief overview of earlier developments. The earlier work related to the case studies featured in this article, the two shipwrecks and the Heinkel He 115 seaplane, is appropriately utilized. Adding explicit connections to the current paper would enhance clarity, particularly regarding which technologies are now used and where they fit into the present work.

The Proposed Method

The timeline provides a well-structured and clear framework for the entire mission. However, the different parts should be more closely tied to the following sections. The authors might consider noting in the subdivisions "Planning a Mission" and "Running a Mission" which parts of the timeline are currently relevant. This would create a more unified feel throughout the paper.

Planning a Mission/Running a Mission

The results presented are impressive and clearly articulated. The ORB-SLAM3 system, in particular, appears highly valuable, and its benefits are effectively conveyed. In the section on surface reconstruction, it might be beneficial to expand on the reference to running Poisson Surface Reconstruction incrementally (lines 202–203) to provide more context and possible use cases. Additionally, it would be helpful if the authors offered a

recommendation on whether PSR or BPA is preferable, helping readers understand the rationale for including this part as a whole.

Processing a Mission

This section offers a comprehensive overview of the data processing workflow, from filtering and preprocessing visual data to the Structure from Motion (SfM) process for 3D reconstruction. It highlights the unique challenges in underwater photogrammetry and addresses them well. The paper does not mention whether image preprocessing was performed, and if it was, which software and techniques were employed. In other instances, the software and tools are appropriately introduced (such as in the case of MeshLab in lines 360–362).

Discussion/Conclusions

In light of the earlier concern regarding the lack of connectedness between the subsections, the Discussion should contain direct references to the paper itself. Similarly, the Conclusions should offer an argumentative assessment of the proposed novel methodology's strengths and weaknesses. These considerations could also be discussed in relation to future real-world experiments.

Figures and References

The figures and pictures are generally of high quality. They are adequately referenced in the text, with the exception of Figure 14. The references are correctly listed, and all of them are cited in the main text.