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

Response to recommender

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 constructive and significantly valuable. By carefully addressing each of your comments, we believe that we managed to enhance the quality of our paper. Below 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

Review #1

Methods

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.

- *Indeed, it is something that we are currently working on. At the moment, we lack unfortunately of enough data from different work contexts for comparative results for this current paper, but it is something that we are planning to integrate in our next papers.*

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.

- *We appreciate this specific comment a lot, as it helps us recognize the dimension of the integrity that a methodological framework should usually demonstrate. Our perspective on the need for customizing predetermined practices comes from the demanding nature of underwater*

archaeological sites, that are usually inaccessible or in harsh environments and conditions like deep and open seas, turbid waters or under fast disintegration rates, and the underwater documentation has to be as cost-effective as possible.

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).

- *We added the word timescale in each bar, so that it is clearer to what unit they refer to.*

Review #2

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.

- *In order to enhance the cohesion and unity of the paper we summarized our proposed method in lines 169-186, and added more references of the Figure 3 that shows the interconnection of the three phases, into the text (lines 169, 224, 263). The three phases could indeed be expanded to three individual standalone papers, but conducting a detailed technical analysis for each of the three subdivisions is beyond the scope of the current study.*

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.

- *In the abstract, we added direct references of the methods in lines 7-10, we introduce the innovative robot in line 13, and the contribution is reflected through the text from line 3 to line 14.*
- *In the introduction, we elaborated more on the contribution of the paper in lines 76-85.*

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.

- *In lines 151-167 we added which technologies and methods were used in each case.*

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.

- *In order to unify the three phases of a robotic mission we summarized our proposed method in lines 169-186, and added more references of the Figure 3 that shows exactly the interconnection of the three phases, into the text (lines 169, 224, 263).*

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.

- *In lines 341-344 we added a conclusion on the use of PSR and BPA based on our experiments.*
- *In lines 344-346 we added a note that although ORB-SLAM3 produces a 3D point cloud theoretically in real-time, currently we did not have access to an API (Application Programming Interface) for our experiments with PSR and BPA.*

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).

- *In lines 370-372 we added the CLAHE algorithm that we used for image preprocessing of underwater data.*

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.

- *By adding the paragraph in lines 434-445, we re-structure the research question and the way we investigated to address it through our 3-phases method. We highlight that the method takes a technical and challenge/solution-oriented perspective on underwater archaeological fieldwork, recognizing its potential but also acknowledging oversimplifications and the need for theoretical considerations to connect technological developments with archaeological research discourses.*
- *We also summarized the strengths and weaknesses of our method in Table 1, while referring to them in the text too (lines 442, 447).*
- *We modified the future directions of our research in the paper, by adding a relevant paragraph in the Discussion in lines 447-467, where we highlight our interest on the innovative technology of the snake robot Eelume.*

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.

- *Addressed in line 387.*