Martech 2024.
Marine Technology Workshop
06, 07th June. Palma, Balearic Islands, Spain

Low-lux oriented photogrammetry system for underwater environment modelling

Luis Rodríguez-Cobo[1], Pablo Roldán-Varona[2,3], Pedro Anuarbe[2],
Elvira Álvarez[4], Maite Vázquez-Luis[4], Salud Deudero[4],
David Díaz[4], Francisco Sánchez[5], Elena Prado[5], Adolfo Cobo[1,2,6]

[1] *CIBER-BBN, Instituto de Salud Carlos III, Spain (luis.rodriguez@unican.es)*
[2] *Photonics Engineering Group, Universidad de Cantabria, Spain*
[3] *Institute of Photonics and Quantum Sciences, Heriot-Watt University, United Kingdom*
[4] *Instituto Español de Oceanografía, Centro Oceanográfico de Baleares (IEO-CSIC), Spain*
[5] *Instituto Español de Oceanografía, Centro Oceanográfico de Santander (IEO-CSIC), Spain*
[6] *Instituto de Investigación Marqués de Valdecilla, IDIVAL, Spain*

***Abstract* – This paper presents an optoelectronic design for high-definition imaging in low-light underwater environments. By integrating a high-performance camera with a custom-designed electronic system, we obtain a photogrammetry system capable of being integrated into an ROV or operated by divers to obtain high quality images of marine habitats and species. These images are then processed to obtain a three-dimensional reconstruction of the environment and allow detailed monitoring.**

***Keywords* –** *3D reconstruction, underwater, photogrammetry, optoelectronic design, environmental monitoring.*

I. INTRODUCTION

The health and conservation of marine ecosystems hinge on our ability to monitor and understand them, thus innovative approaches that minimize disruption to these delicate environments is highly needed [1]. Traditionally, extractive methods like dredging have been employed for studying marine habitats, but their invasive nature poses a threat to the very ecosystems under investigation; and on other hand, the in-situ sampling by scuba divers is constrained by the total time you can spend underwater. Recognizing the imperative for non-destructive monitoring and to optimise the number of parameters to be measured, recent advancements in technology, particularly the application of Structure from Motion (SfM) photogrammetry [2], have emerged as a promising solution. This science of reconstructing three-dimensional objects from two-dimensional images offers a transformative avenue for studying the intricate structures of underwater habitats and species. Despite the challenges posed by underwater conditions, SfM provides a unique opportunity to gather highly detailed and accurate information, comparable over time, contributing to the sustainable management and conservation of marine ecosystems.

More traditional methods often fall short in providing access to these unique ecosystems due to their harsh conditions and intricate structures [3]. Therefore, there is a compelling need for cutting-edge technological tools, such as specially designed underwater systems, capable of navigating and capturing imagery in these extreme environments [4]. The development of these systems is not merely a technological pursuit, but a necessity driven by the requirements to monitor marine habitats. In this work, a new optoelectronic system for underwater photogrammetry is designed and tested in complex environments such as underwater caves. The system addresses specific challenges associated with data acquisition in these conditions, including low light levels, imprecise positioning, and limited access time to the sampling area.

II. SYSTEM DESIGN

A photogrammetry module has been designed and built, consisting mainly of a video camera, two LED technology spotlights and environmental sensors, all integrated in a housing submersible to 150 meters, and two laser pointers for image scaling. The main element of the module is a professional cinema camera, Blackmagic Pocket Cinema 4K video camera (Blackmagic Design, San Francisco, USA) with a Micro Four Thirds sensor with proven low-light performance. To complete the optical design, a compact 12 mm f2.8 prime lens has been chosen, offering a good compromise between field of view, brightness and compactness. For ease of integration, a virtual interface module has been designed to connect via Bluetooth to the camera, allowing one to control camera parameters, while connecting with other systems using a standard RS232 interface. This RS232 interface was implemented to allow the possible integration of the photogrammetry system into other systems such as small ROVs. Both the camera and its virtual interface are integrated into a POM (Polyoxymethylene) housing specially designed to withstand the pressure. A commercial acrylic dome WAP 5" acrylic from Hugyfot is incorporated into this housing, being the element that limits the maximum depth of the module to 150m.In addition to the main camera module, a remote control for divers has been designed and implemented in which the control commands for the main module are generated. This remote control consists of two magnetic switch panels that are connected to a microcontroller of the same family (ESP32) inside an auxiliary watertight tube in which the necessary batteries for the whole system are also included.

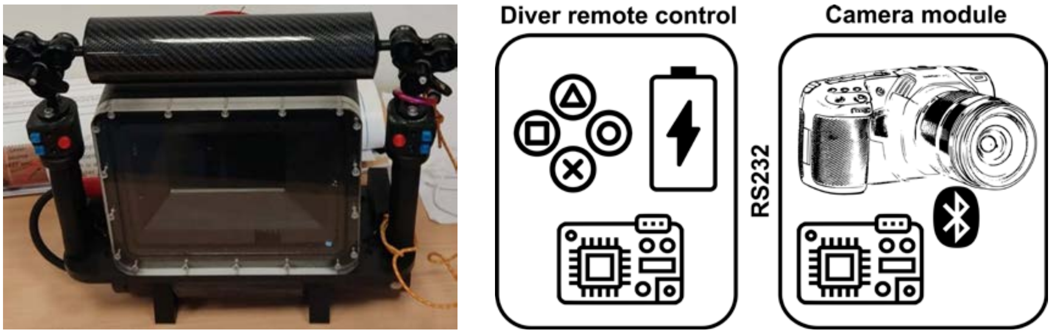

Fig 1. Photo of the photogrammetry system (left). Control system block diagram (right)

III. FIELD TEST

The photogrammetry module assembled with the diver remote control has been tested in different lighting conditions. One example of use was the reconstruction of species living in underwater caves employing the Structure from Motion technique. The employed testing dataset was acquired during an oceanographic campaign in the Maritime-Terrestrial National Park of the Cabrera Archipelago. Several images around the vulnerable bivalve species *Pinna rudis* located in a low-lux cave have been acquired for their further processing by the SfM technique using the RealityCapture software. The 3D model allows for a series of measurements that accurately describe the morphometry of the engraved specimens. An image with the reconstructed model and some off-line measurements over the 3D model are depicted in Figure 2.

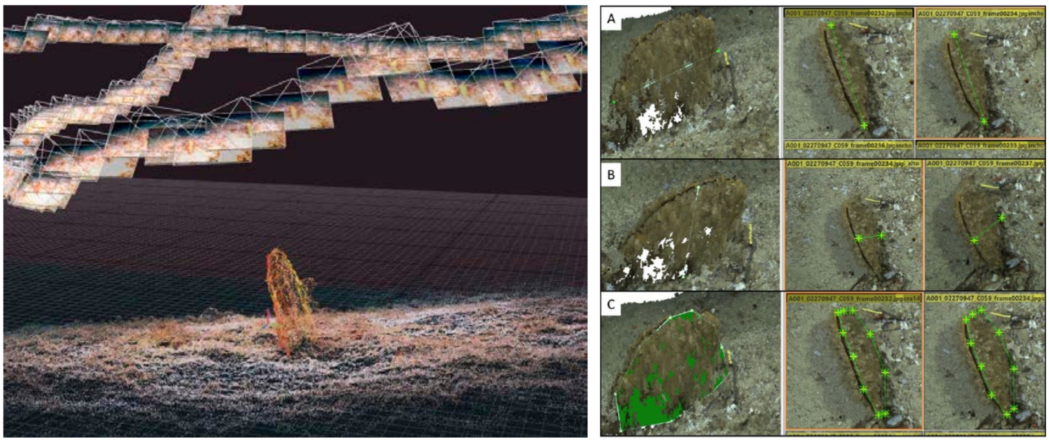

Fig 2. Example of a 3D model reconstructed using the images of the photogrammetry system (left).
Some examples of off-line measurements of *Pinna rudis* specimens over a reconstructed model (right)

IV. CONCLUSIONS

In this work, a new photogrammetry system has been designed and tested to obtain high-resolution images of low-lux underwater environments. The acquired images have been used to obtain a high-resolution 3D model which allows to obtain a more exhaustive analysis of the monitored area, reducing the data capture time and increasing the information available on the monitored habitat. The methodology has been verified through a cross analysis of in-situ measurements on the specimens with those obtained from the three-dimensional model. This work is part of the VirtualMar project (funded by OAPN), PDC2021-121172-C21 and TED2021-130378B-C21 projects funded by MCIN/AEI/10.13039/501100011033, FEDER, and EU NextGenerationEU/PRT. Additionally, it has been partially funded by EsMarEs and BIODIV (order IEO by Ministerio para la Transición Ecológica, Spanish Government).

REFERENCES

[1] Navarro-Barranco C., "Conservation of dark habitats". Coastal habitat conservation. p. 147–170. Cambridge Academic Press; 2023.
[2] Sweeney, C. "Theia Multiview Geometry Library: Tutorial & Reference", Theia Multiview Geometry Journal, vol.39, pp.331−334, 2016
[3] Quiles-Pons, C. "Monitoring the complex benthic habitat on semi-dark underwater marine caves using photogrammetry-based 3D reconstructions". 3rd Mediterranean Symposium on the Conservation of the Dark Habitats, Genoa, Italy, 21-22 2022.
[4] Prado, E. "3D Modeling of Rio Miera wreck ship merging optical and multibeam high -resolution points cloud". The International Archives of the Protogrammetry, Remote Sensing and Spatial Information Sciences, 159–165. 2019