LOW-COST UNDERWATER PHOTOGRAMMETRY WITH ROV AND RGB SENSORS: FIRST IMPRESSIONS

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RESUMEN. Este trabajo trata sobre tecnologías de bajo coste para la cartografía y modelización de ambientes submarinos mediante fotogrametría y teledetección, ya que las tecnologías utilizadas actualmente tienen costes muy elevados, lo que supone un obstáculo para investigaciones con bajo potencial económico. El principal objetivo de este trabajo es verificar la calidad de los modelos 3D submarinos obtenidos con Metashape y cámaras de bajo coste, tras analizar la precisión y resolución y parámetros del modelo resultante, además de entender cómo funcionan las cámaras de bajo coste para cartografía submarina. . Para ello se creó en el laboratorio un equipo con 5 cámaras con sensores RGB acoplados a un ROV (vehículo operado remotamente), capturando fotografías en un intervalo de tiempo predefinido. Los resultados fueron modelos digitales de la superficie submarina, lo que nos permite concluir que este sistema puede convertirse en una solución económica para verificar localmente la calidad de la medición proporcionada por otros productos batimétricos, para el control de calidad, especialmente a nivel de usuario, pero también en trabajo de investigación.

Palabras-clave: Modelado submarino; Detección remota; Modelo.

RESUMO. Este trabalho trata de tecnologias de baixo custo para mapeamento e modelagem de ambientes subaquáticos através de fotogrametria e sensoriamento remoto, uma vez que as tecnologias utilizadas atualmente apresentam custos bastante elevados, transformando isso num entrave para pesquisas com baixo potencial financeiro. O objetivo principal deste trabalho é verificar a qualidade dos modelos 3D subaquáticos obtidos com Metashape e câmeras de baixo custo, depois da análise de precisão e resolução e parâmetros do modelo resultante, além de entender como funcionam as câmeras de baixo custo para mapeamento subaquático. Para isso, foi criado um equipamento em laboratório com 5 câmeras com sensores RGB acopladas a um ROV (remotely operated vehicle) , capturando fotografias em um intervalo de tempo predefinido. Os resultados foram modelos digitais da superfície subaquática , permitindo assim concluir que este sistema pode tornar-se uma solução barata para verificar localmente a qualidade da medição fornecida por outros produtos batimétricos, para o controle de qualidade, especialmente ao nível do utilizador, mas também em trabalhos de investigação.

Palavras-chave: Modelagem subaquática; Sensoriamento Remoto; Modelo.

ABSTRACT. This work deals with low-cost technologies for mapping and modeling underwater environments through photogrammetry and remote sensing, since the technologies currently used have very high costs, making this an obstacle to research with low financial potential. The main objective of this work is to verify the quality of underwater 3D models obtained with Metashape and low-cost cameras, after analyzing the accuracy and resolution and parameters of the resulting model, in addition to understanding how low-cost cameras for underwater mapping work. For this, equipment was created in the laboratory with 5 cameras with RGB sensors coupled to an ROV (remotely operated vehicle), capturing photographs at a predefined time interval. The results were digital models of the underwater surface, thus allowing us to conclude that this system can become a cheap solution to locally verify the quality of the measurement provided by other bathymetric products, for quality control, especially at the user level, but also in research work.

Keywords: Underwater modeling; Remote sensing; Model.

1. INTRODUCTION

The images captured by underwater vehicles with an optical camera (RGB) allow us to approach the corresponding methodological flow for processing through the use of SfM-MVS (Structure from Motion - multi-view stereo) photogrammetry. The use of photogrammetric software allows the reproduction of the point cloud of the studied element which, properly dimensioned, will give rise to the formation of the final three-dimensional model. Maritime robotics is becoming a powerful tool for remote sensing in shallow waters and offers a wide range of study possibilities without site disturbances. From the techniques used to obtain 3D metric information from underwater features using robots, high-resolution colored point clouds are produced, georeferenced, scaled and used for morphometric measurements as well as to derive fine-scale terrain metrics. These solutions generally have high operating costs. This study proposes a low-cost solution for capturing underwater photographs and analyzing the methodological flow of photogrammetric processing to generate point clouds for a three-dimensional underwater model. This analysis will allow us to understand the efficiency of this equipment in the investigation of coastal infrastructures. This study will be of interest to agents involved in maritime infrastructures, as it will allow greater efficiency and cost optimization when carrying out maintenance and repair campaigns and plans during the useful life of a maritime project.

Obtaining 3D information about underwater elements, whether large areas of the seabed or small submerged areas, has been the target of research and technological development for many decades, given its high interest. Maritime robotics is becoming a powerful tool for remote sensing in shallow seas and offers a wide range of survey possibilities without site disturbances (Scaradozzi et al., 2013). These robotic systems include remotely operated vehicles (ROVs), autonomous surface vehicles (ASVs), autonomous underwater vehicles (AUVs), and unmanned aerial vehicles (UAVs) for shallow water inspections. The applications of these vehicles range from underwater/maritime archeology, biology, geology, security and many others (Kapetanović et al., 2020).

The recent development of low-cost systems, both ROV, AUV and ASV and "underwater camera housings", which allow users' cameras to be submerged to ever greater depths, will undoubtedly see underwater photogrammetry follow in the footsteps of aerial experience with the development of UAVs and the illumination of all types of sensors and equipment. The interest now is to make underwater imaging systems economically accessible to the general public, transforming them into a method accessible to various levels of budgets and investments, promoting a popular and economical solution for underwater investigations.

The objectives of this work are to verify the quality of underwater 3D models obtained with Metashape and low-cost cameras through the analysis of accuracy and resolution and parameters of the resulting model, to understand how low-cost cameras for underwater mapping work.

2.MATERIALS AND METHODS

For this research, a small corner area of the port of Ares (La Coruña, Spain) was selected, which has a breakwater zone, a vertical wall dock and a muddy bottom.

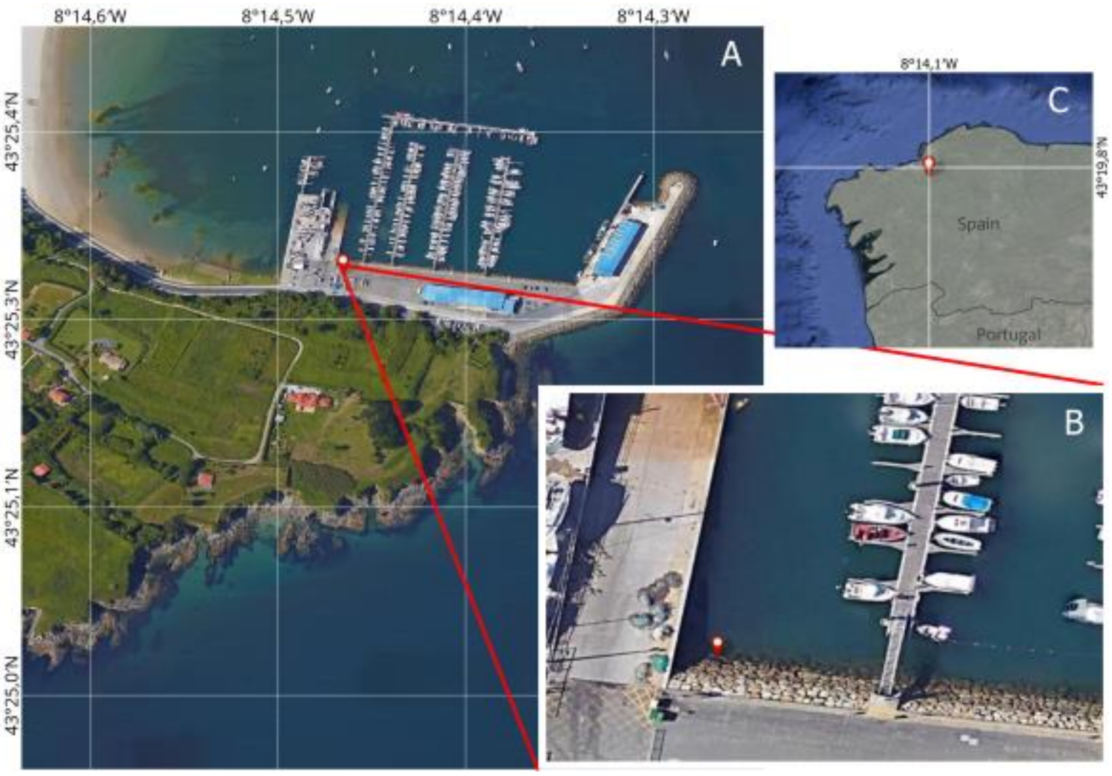

Figure 1: (A) Aerial view of the survey region; (B) Photo of the area;
(C) Location of the study area in Spain.

Source: Google Earth Pro (2024)

To capture the photographs, 5 GoPro Hero 10 cameras were used, programmed in burst mode to take 1 photo every 0.5 seconds. An initial immersion was carried out to test the maneuverability of the set. And then a second immersion was made to photograph the three significant parts of the area, which come together in the corner: the muddy bottom, the pier and the vertical wall of the pier. The cameras were fixed to a support and attached to an underwater vehicle, the ROV Chasing M2 (Figure 2).

Figure 2: (A) 5 GoPro fixed to the support; (B) Support attached to the ROV; (C) Submerged equipment

Source: authors (2024)

An element of known dimensions and geometry was also submerged (a flat slab and two flat and practically coplanar boards, placed at the two ends of a post) (Figure 3). The dimensions of these objects were later used to design the 3D models. 4508 photographs were captured, with the camera programmed to take a photo every 0.5 seconds and ISO 3200. To reconstruct the 3D image, the Agisoft Metashape software was used, which uses the Structure from Motion (SfM) technique to construct a reconstruction of 3D image of the photographed surface.

Figure 3: (A) Submerged element with known geometry; (B) two flat and practically coplanar inserts placed at both ends of a post; (C) flat slab
Source: authors (2024)

3.RESULTS AND DISCUSSION

The modeling had satisfactory results on a local scale. Figure 4 shows the dense cloud of points in a section of the model in the muddy part, a region that presents greater difficulties in representation, due to the presence of loose solid particles that remain in suspension when the ROV approaches, thus increasing the turbidity of the water. . These particles are captured in photographs, becoming physical obstacles to capturing target information. In this type of environment, there is also homogeneity in all areas, with little variation in color and texture, which makes it difficult to identify patterns between photographs.

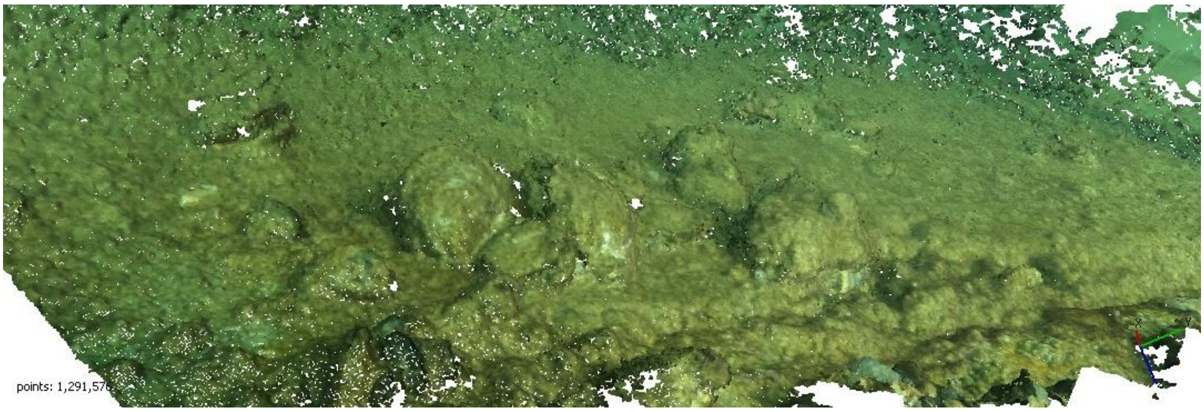

Figure 4: Dense muddy section point cloud
Source: authors (2024)

Figure 5 shows the dense cloud of points from a section of the rocky bottom, which is easier to represent, as they have minimal amounts of particles in suspension, which makes the water more crystal clear and photos sharper. Furthermore, there is also a greater variation in colors and textures, making it possible to identify patterns more assertively.

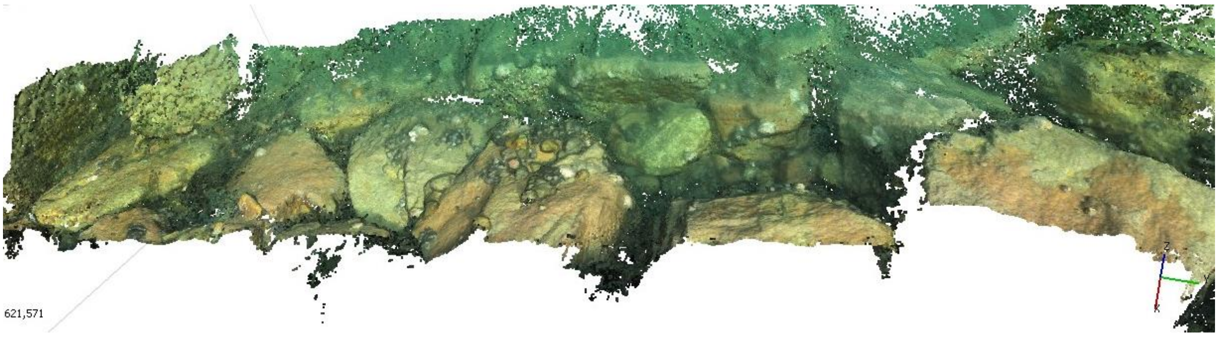

Figure 5: Dense point cloud of rocky bottom section
Source: authors (2024)

Figure 6 shows the section (on a muddy bottom) where the object of known dimensions was positioned to verify the precision and accuracy of the model. Note a satisfactory representation, well-defined corners and verticality of the preserved flat slab.

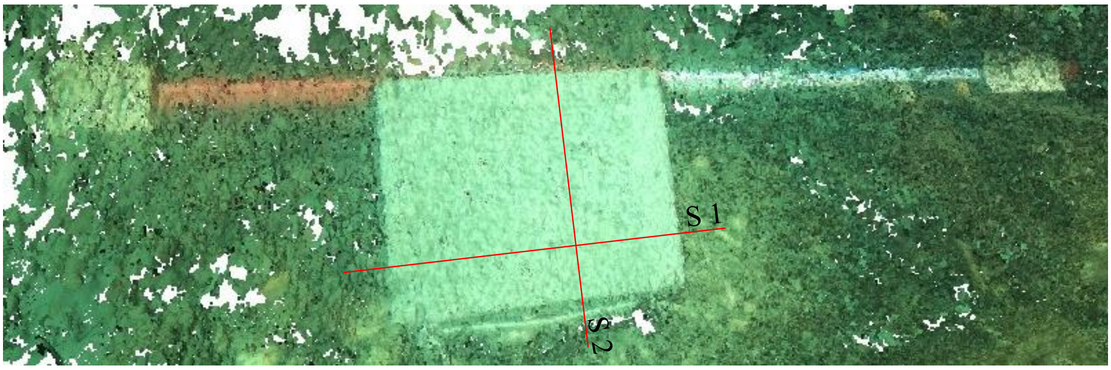

Figure 6: Dense point cloud of the known object, with identification of the analysis sections
Source: authors (2024)

The model was scaled to a real scale based on the known dimensions of the object assembled in the laboratory. To determine accuracy, the dense cloud of points from the slab was separated and its flatness was subsequently checked. Two sections were then defined, approximately perpendicular to each other, and the x, y and z coordinates of the points contained in these sections were tabulated, totaling 352 points in section 1 and 493 points in section 2. These points were plotted, in order to graphically represent the elevation of the two sections.

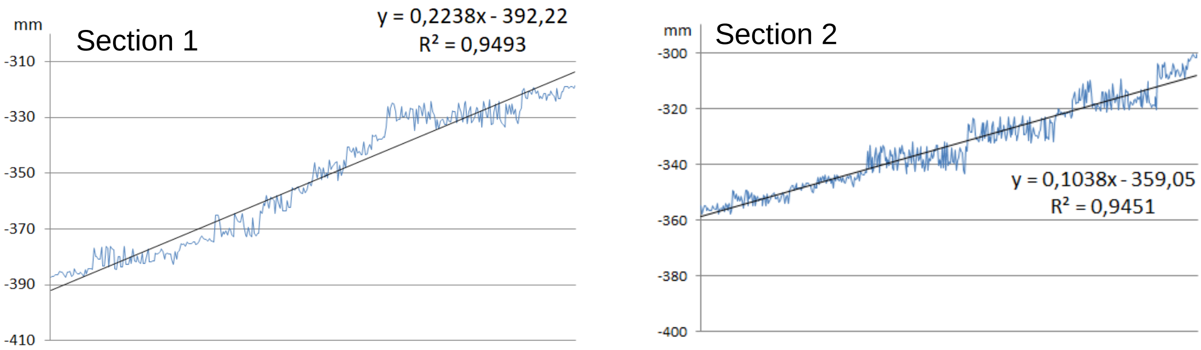

Figure 7: Graphical representation of sections 1 and 2 and linear regression function
Source: authors (2024)

With this, the maximum positive and negative errors, the standard deviation of the error and the coefficient of determination R^2 were calculated. A linear regression defined by a first degree function was considered, since the profile of the real surface of the flat slab is represented by a straight line. The slope of the straight line is due to the fact that the muddy underwater surface on which the slab is supported is not perfectly flat, which results in the slab being supported on an irregular surface and having its surface represented in slope.
Table 1 shows the values of the model's accuracy indicators for both directions:

	Standard deviation	Maximum positive error	Minimum positive error	R^2
Section 1	5,2458	16,1098	-11,1114	0,9493
Section 2	3,5572	9,3032	-11,4756	0,9451

Table 1: Model accuracy indicators
Source: authors (2024)

With this, an accuracy of the order of ±2cm can be stated, with a percentage of points with a representation well adjusted to the model. Since there was a very high overlap between the photos, a model with high precision was to be expected. However, despite the reduced costs with capture equipment, this high overlap generates an exaggerated number of photos, which increases the cost of modeling in the laboratory, given the need for powerful computational machines and high processing time.

4.CONCLUSIONS

This system can become an inexpensive solution for locally checking the measurement quality provided by other bathymetric products, for quality control of other products, especially at user level, but also in research work. In other words, an efficient method to control the quality of bathymetry work carried out with single-beam and multi-beam probes. This is increasingly important nowadays, firstly because these are generally expensive jobs and because new techniques are also being increasingly used (such as radar or lidar) and mounted on UAV, remotely controlled boats. Having a contrasted quality measurement method is interesting, so that, for example, small samples of point clouds are collected at different locations in the study area and can be compared with the point cloud obtained with other techniques (sonar, lidar, radar...) in these same areas. This way, stakeholders would have a reference of the measured quality of the work delivered. Even more detailed studies must be complemented, in order to reduce processing time and computational "effort" of processing.

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