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3D modeling of underwater objects using photogrammetric techniques and software comparison

Seda Nur Gamze Hamal[*1], **Ali Ulvi** [1]

[1]Mersin University, Institute of Science, Remote Sensing and Geographical Information Systems, Mersin, Turkey

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ABSTRACT

Most of the earth is covered with water. Most of these waters are oceans. Despite the fact that so many areas are covered with water, research on underwater photogrammetry is not as numerous as above ground research. However, in recent years, with the integration of cameras underwater, researchers have turned to underwater photogrammetry studies. In this study, it presents research on whether the selection of SfM-based software is suitable for the underwater environment. In the research, data collection was carried out by placing an object in a 1.5-meter-deep pool. In the data processing part, Agisoft Photoscan, Context Capture and Reality Capture software were used and 3D point cloud data were obtained and evaluated from each software.

1. Introduction

About 70% of the world is covered by water. While people are doing their research very comfortably on earth in the world they live in, the situation is not the same under water. The discovery of underwater life, archaeological remains, biological resources have remained secret for many years. However, in recent years, researchers have turned to underwater research, thanks to the ability to integrate cameras underwater and additionally technological innovations such as underwater drones. Thus, subjects such as the documentation of archaeological remains, the increase and decrease in biological diversity began to be studied. The most adopted method in these studies was underwater photogrammetry (Block et al., 2017; Polat et al., 2020).

Underwater photogrammetry is based on various systems and methodologies. The optical properties of water and lighting conditions seriously affect underwater images. Because light absorption mostly affects red wavelengths, colors are absorbed at different rates as depth increases, resulting in a green-blue image. Water also absorbs light energy and scatters optical rays, creating blurry images. These conditions hindered underwater photogrammetric studies. However, thanks to the SFM-based software developed in recent years, it affects these situations relatively less (Raoult et al., 2016; Casella et al., 2017; Vlachos et al., 2018; Yakar et al., 2015).

The rise of photogrammetric software packages has aided underwater photogrammetric studies that were nearly impossible before commercial software using SfM algorithms. As the commercial software market has expanded in recent years, many software packages using the sfm algorithm have emerged. In this case, it has been a matter of debate which of the several photogrammetric software packages available on point clouds of the underwater environment can provide better results (Drap et al., 2015; Çelik et al., 2020; Sefercik et al., 2020; Ulvi et al., 2020; Yiğit et al. Uivi, 2020).

Mangeruga et al. (2018) collected data from various underwater areas with different depth, turbidity and lighting conditions in their research. These data sets were compared by generating point clouds in different software. In their study, Burns and Delparte (2017)

* **Corresponding Author**

*(sedanurgamzehamal@gmail.com) ORCID ID 0000 – 0002 – 1050 – 3088
(aliulvi@mersin.edu.tr) ORCID ID 0000 – 0003 – 3005 – 8011

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obtained the 3d point cloud in Agisoft and Pix4D software by collecting data on underwater coral reefs at different camera angles and at different heights. Then, they compared the errors of these two software and compared the obtained point clouds by performing Welch t-test statistical analysis. In their research, Vlachos et al (2019), after collecting data from an archaeological site, processed it in Agisoft Photoscan, VisualSFM, SURE, 3D Zephyr and Reality Capture software. Then, they made a comparison between the software by making cloud to cloud and surface density analyzes. In this direction, data were collected by placing an object in a pool 1.5 meters deep. It was processed using Agisoft Photoscan, Context Capture and Reality Capture software to process the collected data. Agisoft Photoscan is the most used software to obtain 3d point clouds in the literature. For this reason, the point cloud data obtained from this software was accepted as a reference and analyzes were made in CloudCompare software.

2. Method

2.1. Data collection

In the study, 80 overlay photographs were taken underwater.

For this purpose, Go Pro Black Hero 9 camera was used to collect the data of the underwater object. The technical information of the camera used in the study is shown in Table 1.

Table 1. Technical properties of Go Pro Hero Black 9 camera

Technical properties	Value
Sensor	1-Chip CMOS
Sensor Resolution	23,6 MP
Media Recording	1 x microSD / HC / XC (256 GB Maximum)
Still Image Support	JPEG - 20 MP
Shutter Speed	1/25 - 1/2000 Second (Photo)
Ptoho ISO Range	100 - 6400
Video ISO Range	100 - 6400
Image Stabilization	Digital
White Balance Modes	Auto

2.2. Data process

Agisoft Photoscan, Context Capture and Reality Capture software were used for photogrammetric evaluation. In all software used, it was paid attention to be in the same reference system while generating the point cloud.

The point cloud generated in Agisoft Photoscan software was accepted as a reference. This is because underwater photogrammetry is the most widely used software (Demesticha et al, 2014).

The following statistical results were obtained in the Cloud Compare software, which is the open-source software of the 3D point clouds produced.

In this software, analyzes were made based on surface density and roughness values.

Surface Density is estimated by counting the number of N neighbors for each point (within a sphere of radius R). The surface density used for this evaluation is defined by dividing the number of neighborhoods by the neighborhood surface. The software estimates the surface density for all points of the point cloud and then proportionally calculates the average value for an area of 1 m^2. Surface density is considered a positive metric because it describes the number of points on a potentially generated surface, excluding noise that is present as points outside that surface. This is why the surface density metric is used instead of the volume density metric.

Roughness The “roughness” value for each point is equal to the distance between that point and the optimal plane calculated at its nearest neighbors, which are points in a point-centered sphere. Roughness is considered a negative metric as it is an indicator of noise on the point cloud, assuming a generally smooth surface.

To facilitate an overall comparison of the tested software in terms of 3D reconstruction performance and to evaluate numerous outcomes, the surface density D and roughness R metrics have been normalized. Purposely, the metrics and results obtained are presented from a critical perspective, highlighting the pros and cons of each software for the dataset used. Following this, a general conclusion is reached as to which of the three software packages mentioned above performs best in this particular environment and for this particular dataset.

3. Results

First of all, the data obtained during the photogrammetric processing process was created as 3d point cloud data in Agisoft Photoscan, Context Capture and Reality Capture software, respectively. While the total process time was 98 minutes in Agisoft Photoscan software, it took 85 minutes in Context Capture software and 105 minutes in Reality Capture software.

In order to compare the obtained point clouds, Roughness analysis was first performed in Cloud Compare software. (Figure 1). The roughness calculation is called the shortest distance between the optimal plane calculated on the nearest neighbors of each point in the point cloud (Cloud Compare, 2021). Purpose of analysis, the lower the value in the legend part, the less jagged the point cloud is.

Roughness analysis was performed separately on the point clouds obtained as a result of all software. As a result of the analysis, the values found in the legend were normalized with the help of the equation given in equation 1. This is because it makes values visible and easy.

$$Z = \left(\frac{X - \min(x)}{\max(x) - \min(x)}\right) \quad (1)$$

By normalizing the values in the roughness analysis of all point clouds, the values of 9 mm in Agisoft Photoscan software, 8 mm in Reality Capture software and 3 mm in ContextCapture software were found.

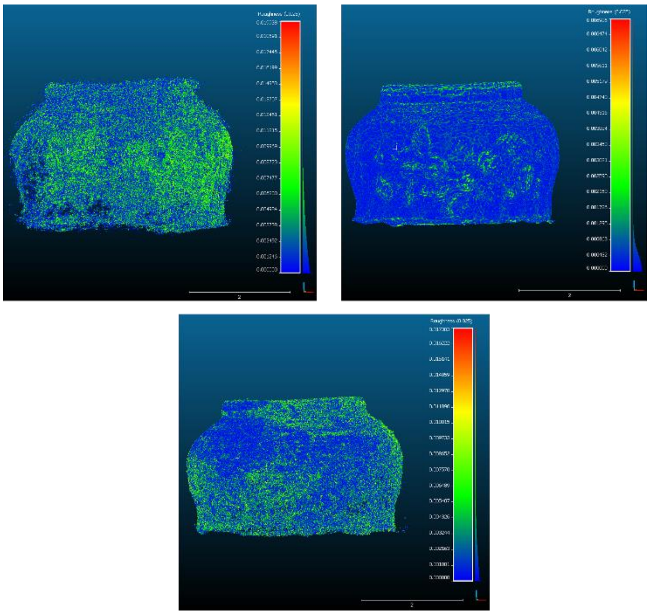

Figure 1. Roughness analysis in point clouds

Surface density analysis was performed in CloudCompare software to find the surface density of the model. The same calculations as in the roughness analysis were also used for the surface density analysis (Figure 2).

In the tested point clouds, it was noticed that the overall visual representation of the dense point cloud was better at medium quality as it appeared denser and less noisy.

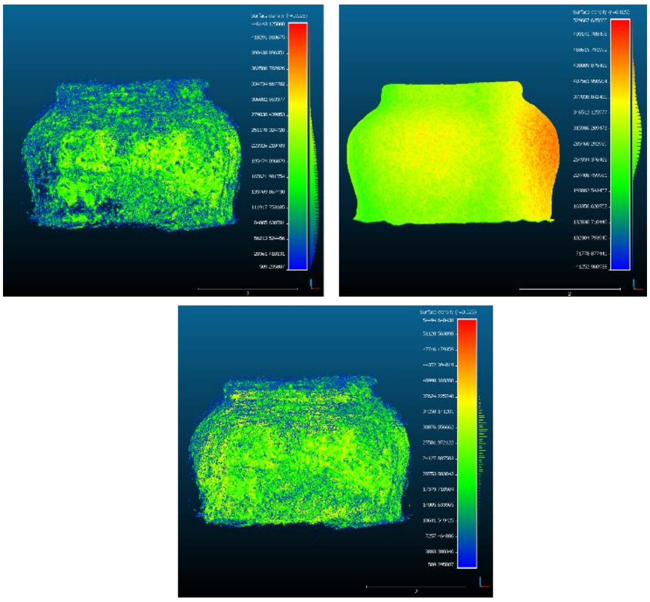

Figure 2. Surface density analysis in point clouds

As shown in Table 2, the number of points produced per point cloud varies considerably. Context Capture produced a much larger amount of points. On the other hand, Reality Capture and Photoscan appear to produce less point clouds. This potentially shows that the parameters used in sfm algorithms Reality Capture and Photoscan are very similar to each other.

Table 2. Number of point clouds produced by 3 different software, average surface density and average roughness

Software	number of point clouds	D	R
Agisoft Photoscan	1369087	282573.2692	0.009968706
ContextCapture	13196754	36678.44271	0.003452824
Reality Capture	1358769	260648.5283	0.008651706

4. Conclusion

Based on the evaluated metrics, it can be concluded where each software has grown and fallen. All software appears to produce complete point clouds.

However, it was noted that it was completed at different times during the process. Although there is not much difference in the process time of a small object, it is predicted that this time will be much different in the process of larger areas. For this reason, it is thought that the software should be selected according to the characteristics of the area to be studied.

While the number of point clouds was almost the same in Agisoft and Reality Capture software, ContextCapture software almost doubled the number of point clouds compared to the other two software. Having a large number of point clouds helps to see the details of the object better, but it can cause problems in terms of data storage. For this reason, software selection should be made according to the purpose of the study.

From the metrics evaluated during this particular study. Additionally, seeing results regarding roughness, it is notable that reality capture outperforms other software. Unfortunately, no clear conclusions can be drawn regarding surface density metrics as the number of neighboring points is proportional to the total number of points the point cloud has. Considering everything about point cloud integrity, number of points, point distribution and all the metrics evaluated, it can be said that the software used may be the best options for the generation of 3D dense point clouds underwater. Although some photogrammetric softwares seem to be more advantageous than others from these comparisons, the results of the dataset obtained with a single measurement may not be reliable. For this reason, it was concluded that more than one measurement should be evaluated in different underwater conditions, where the depths are variable and even the season and measurement times are different. Therefore, in the future, further evaluation with different datasets under different conditions may yield tangible results as to which photogrammetric package produces the best overall 3D point clouds in an underwater environment.

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