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Investigation of Underwater Photogrammetry Method: Challenges and Photo Capturing Scenarios of the Method

Seda Nur Gamze Hamal*[1]

[1]MersinUniversity, Remote Sensing and Geographic Information Systems, Mersin, Türkiye

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Abstract

Three-dimensional (3D) documentation of an underwater object and its transfer to digital platforms have gained worldwide importance in recent years. For this purpose, the photogrammetry method has been tried underwater and the term underwater photogrammetry has found its place in the literature. The most important reason for preferring the photogrammetry method is that it collects data in a shorter time compared to other methods and provides a positive contribution in terms of time and cost. However, there are both environmental and physical limitations in the underwater photographic data collection process. Various suggestions have been made to minimize these restrictions. The method, in which three-dimensional (3D) data can be produced from moving records of objects known as Structure from Motion-SfM), is also used in underwater photogrammetry. In addition, software used in other photogrammetry methods can also be used in underwater photogrammetry. But in the applications made: According to the photographs taken by other photogrammetry methods, in the photographs taken under water; It is foreseen that some corrections such as color and contrast correction, shadow removal and highlight reduction should be applied with image processing before they can be evaluated in software. Like other photogrammetry methods, underwater photogrammetry has kept pace with technological developments.

1. Introduction

Underwater photography requires special skills, experience and difficulties that require detailed work. These difficulties are being able to see living things and colors, taking shots without damaging them, using the right light and equipment according to the subject, correct timing, keeping diving safety and taking photos according to the purpose of the work. In recent years, studies have been carried out frequently in the fields of military, civil and academia with underwater photography. At the beginning of these studies, it includes many subjects such as the detection of archaeological sites, monitoring of underwater ecosystems, exploration of underwater resources, target positioning and identification. Underwater photogrammetry is the most widely used method for these subjects. Underwater photogrammetry, which is a sub-branch of photogrammetry, enables to determine the position, shape and size of objects and to extract 3D information with the help of photographs taken (Anelli et al., 2019; Baletti et al., 2015; Barnes, 1952).

The biggest advantage of the underwater photogrammetry method is the contribution it provides in terms of time and cost. Since this method can produce base data and models for many disciplines, it is frequently preferred for different purposes and directions. Especially with the developments in computer technology, the Structure from Motion (SfM) algorithm, as well as the photogrammetry technique, offered new perspectives to the operators in the use of this method. With this algorithm, the camera calibration parameters previously calculated by the operators can be calculated directly through software. The 3D geometry of the structure or object to be created with this algorithm is solved by finding the matched detail points in at least two photographs obtained by using different perspectives during the measurement. With the

* **Corresponding Author**

*(sedanurgamzehamal@gmail.com)

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advantages provided by the SfM algorithm, changes have also emerged in photography with the photogrammetry technique. In order for the SfM algorithm to perform at an optimum level, it is necessary to take sequential photos. While sequential photography can be done easily on the ground, the situation is different under water. There are fundamental difficulties in photographing underwater photogrammetry. In this study, the main difficulties of underwater photogrammetry are mentioned and photography techniques are examined within the framework of these difficulties (Burns and Delparte, 2017; Casella et al., 2017).

2. Method

It is very important to have good planning because of sudden changing weather conditions, underwater currents, water movement and limited time underwater. In order to shoot in accordance with the photogrammetric shooting principle, an experienced and competent diver is needed in the underwater environment. Especially in photogrammetric studies performed by the diver in shallow water, problems such as camera position, camera angle, camera movement speed and image stabilization may occur, since the buoyancy of the water cannot be controlled.

Unpredictable underwater environment, unpredictable weather change creates shadow problem and reflection problem. Artificial light sources integrated into the underwater housing may be required to help with these problems (Mallet and Pelletier, 2014; Menna, 2016; Figure 1).

Figure 1. Housing and artificial light source

The blowing caused by the wind causes the sun's rays on the water surface to vibrate and thus shiny textures called caustics occur on the water floor or the objects on the bottom (Agrafiotis, 2018). Caustics are undesirable for photogrammetric applications. This is because it affects the extraction of two-dimensional content data from the photo as well as creating poor quality object texture. The intensity of the light caustics depends on the slope of the sun angle, water turbidity and depth, but after a few meters, the effect gradually decreases (Menna 2016; Kaya et al., 2019). In his study, Menna (2016) argued that it is necessary to use artificial light sources such as electronic flashes in underwater environments, especially in deep places, because both the colors can be reflected as they are and the aperture due to the limited viewing angle can be compensated. As a general rule, in waters up to 10 meters deep, diffraction effects, called caustics, can be a problem for active radial sensors (Hamal et al., 2022; Figure 2).

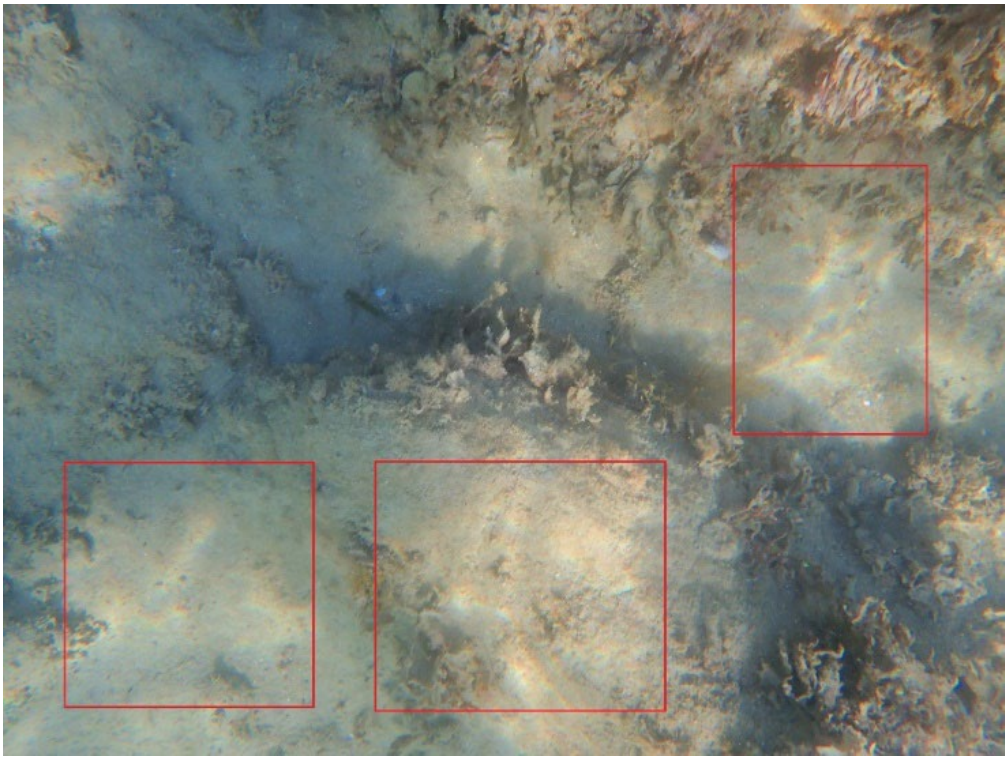

Figure 2. Underwater caustic

Agrafiotis et al. (2018) stated that although photogrammetric applications in deep waters are carried out at noon when higher brightness conditions are provided, strong artificial light sources are needed due to reasons such as providing the image coverage ratio in shallow waters, the sun in a low orbit, and avoiding artificial images on the sea surface. In addition to all these light-based problems, problems may arise due to the inability to control the buoyancy of the water in photogrammetric studies performed by the diver in shallow waters during the data acquisition phase (Hamal and Ulvi, 2020). Accordingly, the waves can strain the balance of the diver and the camera. All these situations can of course cause difficulties in deep waters due to the flow of water. It is not a preferred method when the distance between the camera distance and the imaged object is short enough to be less than 1 meter in studies conducted in shallow waters. Because the point where the camera is positioned cannot be marked exactly, the amount of data to be processed increases, the image scale grows, and this causes the storage capacity to be larger with the increase in data processing time. In some unusual situations there may not be enough space for the diver and the camera. To overcome this, either lenses known as fisheye or bi-media photogrammetric approaches such as water-to-air or air-to-water are applied (Hamal et al., 2021).

The loss of different wavelengths due to varying depths is a challenge in underwater photogrammetry. Water absorbs different wavelengths of light to varying degrees. The longest wavelengths with the lowest energy are absorbed first. The first absorbed is red, then orange and yellow. Colors fade underwater in the order they appear in the color spectrum. Water also absorbs light energy and scatters optical rays to create blurred images (Raoult et al., 2016; Casella et al., 2017; Vlachos et al., 2019). There are several ways to reduce the difficulties of lighting and color in underwater images. But fixing one difficulty can often create another. The photographer may have to decide between better image, color or better image quality. The exposure time of the camera can be increased to obtain better color, but this will result in poor image quality. Certain filters can be added to images to better capture certain wavelengths of light. It will require a filter and artificial lighting to better capture reds, oranges and yellows. These situations hindered underwater photogrammetric workers. However, thanks to the SfM-based software developed in recent years, it affects these situations relatively less (Bianco et al., 2015; Bryson et al., 2016; Nocerino et al., 2020).

Bodies of water are often filled with various floating particles that can obscure vision and interfere with a view. Particles suspended in water include gravel, sand, silt, clay, algae, seaweed, and others. Suspended particles under water affect field work. It is appropriate for operators to be close to objects (depending on water quality) between a minimum of 0.5 m and a maximum of 3 m. However, this makes it difficult to work on large scales. This seemingly limiting aspect requires having to produce a large amount of stereo pairs, but also ensures high accuracy and sensitivity (Maas, 2015; Cheng et al., 2020).

Various particles such as phytoplankton, organic substances, and pollution suspended in the water cause the water to become cloudy, and light is scattered in the water for these reasons. Scattering, or diffuse reflection, occurs due to the random deflection of light from its direction. Scattering; it limits the image quality, reduces the contrast and causes blurry images (Menna et al., 2016; Nocerino et al. 2021; Figure 3).

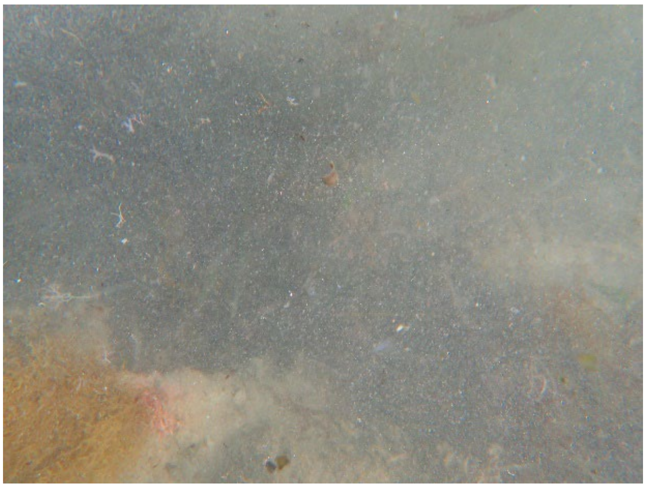

Figure 3. Blurry image underwater

Sea water is 800 times denser than air. All these dimensions vary depending on each other: as the temperature increases, the density increases, as the pressure increases, the salinity increases, and the pressure increases by 1 atm for every 10 meters of depth, in direct proportion to the depth. This corresponds to a change of 1.033 N/cm2. In this case, it affects underwater photogrammetric studies (Kaya et al., 2019).

3. Underwater Photo Shooting Scenarios

Shooting scenarios in underwater photogrammetry are very important in terms of the quality of the images to be captured and the accuracy of the resulting models. For this reason, shooting scenarios to be used in underwater photogrammetry must be created correctly.

Underwater surveying projects are quite challenging compared to the normal indoor/outdoor imaging procedure due to the fundamental challenges. Therefore, it is necessary to plan the shoot carefully before conducting a real shooting session. It is always better to take more images than necessary than to have insufficient image overlap or an incomplete dataset. It has been suggested to wait for as much calm air and bright light as possible to increase the visible distance. In addition, when shooting underwater, lighting or a fixed light source that will increase the visible distance and quality of the images obtained should be used.

It has been emphasized in the literature in underwater photography scenarios that it is necessary to shoot using "snake" or "spiral" routes (Figure 4).

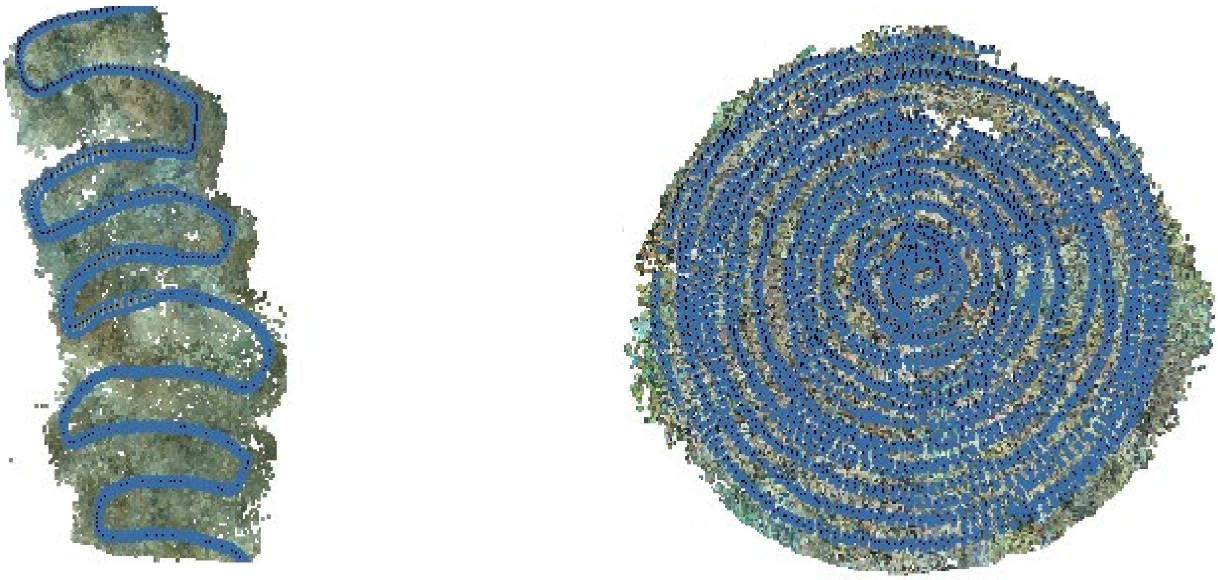

Figure 4. Snake (Left) and Spiral (right) photography technique (Yakar et al., 2022).

4. Structure from Motion (SFM)

Photogrammetry is a branch of science that precisely determines the location, position and shape of an object by using photographs taken from different angles (Yiğit and Ulvi, 2020). The advancement of technology and the integration of photogrammetry and computer imaging technology have led to advances in automation of 3D model production with greater flexibility in 3D modeling work (Ulvi et al., 2020). Today, there is a variety of software available that allows us to make 3D models of surfaces from photographs taken with conventional cameras. Most of this software are based on proprietary algorithms such as Structure from Motion (SfM) (Yakar et al., 2016; Ulvi and Yiğit, 2022; Oruç, 2021). SfM; It is a photogrammetric algorithm that automatically solves the geometry of the scene, camera positions and orientation without requiring pre-definition of a target mesh with known 3D positions (Yakar et al., 2022). SfM, which is a measurement method based on computer visualization; It is an inexpensive method that has gained popularity recently because digital cameras, video cameras or smartphones with cameras are used (Döş and Yiğit, 2022; Oruç, 2021). For this reason, its use in scientific research has become very common. SfM algorithm; It has had a transformative impact on geoscience research due to its low cost, extremely fast results and easy 3D measurement capability. In the SfM algorithm, a series of overlapping picture frames is used to create 3D structures. It works by finding and matching commonalities across a series of overlapping photos.

Photogrammetric evaluation software is of great importance for 3D modeling studies. Many commercially used software are in use today. However, according to the content of the work to be done, the choice of photogrammetric software is of great importance. Each software has outstanding capabilities. Here are the most important points; The result is the quality of the product and how many steps and how long the processes will take (Yiğit and Uysal, 2021).

Structure-from-Motion (SfM); is a photogrammetric algorithm that automatically solves the geometry of the scene, camera positions, and orientation without requiring pre-definition of a target mesh with known 3D positions. The 3-dimensional geometry of the scene to be analyzed is solved trigonometrically with the matched detail points in at least two images, by using the difference in viewpoints at the time of image recording. As a result of this process, a 3D point cloud is produced as many as the number of points that can be mapped in a local coordinate system. Software using the SfM technique is based on algorithms for automatic positioning of shared points between images to create a Sparse point cloud. The most widely used algorithm for this process is the Scale-Invariant Feature Transform (SIFT) algorithm, which works on radiometric pixel values (Şenol et al., 2021).

The sparse point cloud created using SfM algorithms is relative and should be calibrated to actual dimensions. This calibration is performed using several known target marks. Another step in SfM is the creation of a dense point cloud. The algorithm used in this step is the Dense Multi View Stereo (DMVS) algorithm. At this stage, the mapped pixels and their estimated 3D positions become point clouds to produce a mesh model. Finally, images are used to give the model a photorealistic texture.

5. Human Health

Another feature of the photogrammetry technique that distinguishes it from other techniques is that it does not endanger human health. However, in underwater photogrammetry studies, this is the opposite. In particular, operators who will carry out underwater photogrammetry studies should receive professional training. Although training is received, it is recommended that no more than three dives per day be made on average due to the accumulation of nitrogen in the body, depending on the depth and duration of a diver's dive, due to human physiology (Figure 2.13). Therefore, the time that divers spend underwater is limited. Therefore, it is necessary to measure in a time that will not adversely affect human health (Kahraman et al., 2012; Kaya et al., 2019; Figure 5).

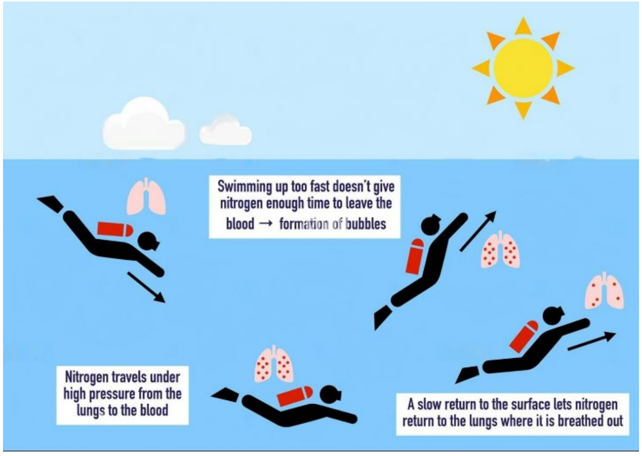

Figure 5. Nitrogen accumulation (Kahraman et al., 2012; URL-1).

6. Discussion and Conclusion

In this article, the issues that should be considered in photography scenarios and human health when applying the photogrammetry method in the underwater environment are presented. Along with the main difficulties affecting the underwater photogrammetry method, the importance of shooting scenarios in these difficulties was emphasized. When created correctly in shooting scenarios, it enables the creation of accurate and high-quality three-dimensional models. For this reason, people who will do underwater photogrammetry need to create shooting scenarios correctly.

The biggest advantage of the photogrammetry method is the contribution it provides in terms of time and cost. Since this method can produce base data and models for many disciplines, it is frequently preferred for different purposes and directions. Especially with the developments in computer technology, besides the photogrammetry technique, the Motion-Based Structural Detection (Structure from Motion/SfM) algorithm has also offered operators new perspectives in the use of this method. With this algorithm, the camera calibration parameters previously calculated by the operators can be calculated directly through software. The 3D geometry of the structure or object to be created with this algorithm is solved by finding the matched detail points in at least two photographs obtained by using different perspectives during the measurement.

The characteristics of digital technologies are accuracy, portability, low cost and rapid acquisition, each of which is important in archaeological sites, especially in shipwrecks with amphora loads. Underwater photogrammetry can be a very useful tool for archaeology. Digital techniques are essential for creating a virtual model with centimeter accuracy. It ensures that reliable 3D models are produced after the geometric accuracy is created. With these methods, one can achieve technically precise documentation. In addition, the versatility of underwater photogrammetry in terms of data acquisition is an advantage of this system. Besides the shallow conditions, it has made it difficult to use the underwater photogrammetry method in deeper areas up to about 35 m where the light conditions have become quite poor. For this reason, it is anticipated that this technique will be useful in deeper areas by placing artificial light on the cameras. In the deep regions, the use of ROVs equipped with cameras has been used in vphotogrammetric studies in recent years. The advantage of this system is that it provides the opportunity to make measurements without the need to dive into deep areas. In addition, it saves time according to the measurement made with the help of divers. The disadvantage is; The unbalanced topographic structure of the underwater area to be photographed makes the measurement difficult. Important advice gained during underwater working experiences is related to the quality of the photos. Shadows, variation in natural light, or artificial shadowing can compromise the alignment of images, causing permanent shadows on the 3D model. Therefore, when choosing to do photogrammetric research in shallow water, in the best weather conditions, it is envisaged to avoid these problems by choosing to increase the ISO of the camera in deep water, without creating any noise in the images. In addition, before the photographs are processed in the software, it is foreseen that image enhancement processes such as color correction, contrast, removing shadows and highlight reduction should be applied to the photographs. It can be used to explore the inaccessible wrecks with a stereoscopic imaging system and to promote underwater cultural heritage information to a wide audience.

Author contributions

The article has a single author.

Conflicts of interest

The authors declare that for this article they have no actual, potential, or perceived conflict of interest.

Statement of Research and Publication Ethics

For this type of study formal consent is not required.

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