Occupancy Grid Mapping from 2D SONAR Data for Underwater Scenes

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***Abstract*—Nowadays, creating a 3D reconstruction of the underwater environment is an important and non-trivial task, as it depends on the application environment and the main goal of the reconstruction, as well as on the information to be extracted on the final map. These reconstructions can allow robots to perform inspection and monitoring or cleaning tasks in different conditions, namely in dams. In these structures, it may sometimes be necessary to activate a cleaning system so that there is no risk of accidents. Therefore, in this work, a method is proposed to obtain a 3D reconstruction of the scene under the sensor based on a Mechanical Scanning Sonar (MSIS) and an external visual-based localization source. The localization is performed by a previously developed system based on the tracking of a visual ArUco marker. The main goal of this preliminary study is to evaluate the performance of MSIS in mapping tasks. Moreover, three different techniques are introduced to filter the measures and ensure that the final information is correct without affecting the systems in terms of memory requirements. Thus, the evaluation is carried out through some experiments on an experimental pool with some objects with different characteristics and building materials. The results show that a value of 50% of gain is the best for the tested materials. Moreover, the shape of the objects can be correctly identified and the obtained dimensions of the objects are adequately estimated. Moreover, the results of a discretization process in terms of x and y coordinates are presented, which allows to reduce the storage cost of the final map.**

***Index Terms*—3D reconstruction, mapping, occupancy grid, acoustic sonar, MSIS**

I. Introduction

Three-dimensional reconstruction is an important field in underwater robotics, mainly because of the amount of unknown information about the underwater environment. Besides being unknown, this environment is unstructured and so collecting data with the quality of perceptual sensors to understand the scenes well is still a challenging task. Optical sensors can provide high resolution images, but their range is limited to a few meters. Therefore, visual systems can be used to create 3D representations of the scene, but their use in underwater mapping is a really difficult task, namely in dark environments. In such situations, artificial light is necessary, but if used incorrectly, it creates some undesirable effects. These limitations can be overcome with acoustic sensors, which are interesting because they can provide information in underwater environments even in poor or no visibility conditions. Therefore, the success of the 3D reconstructions and their quality are crucial to monitor structures, check if there are obstacles near the robot, and detect and recognize some of them in the final map. Therefore, the main goal of this preliminary evaluation is to verify the behavior of MSIS in mapping the scene under the sensor. Thus, it is crucial to understand if this unique and simple perceptual sensor is suitable to identify later the level of sedimentation of conduct of a dam in order to activate a cleaning system (so that there are no accidents).

This paper is organized as follows: in section II, the main related works with 3D reconstruction in underwater environment are described. Secondly, in section III, the main phases of the involved mapping process, the setup configuration required to test the method, and the data synchronization technique are described in detail. In the next section IV, the objects used to test the method, a study of the relationship between the building materials and sonar gain, and the main results in terms of mapping effectiveness are presented. In addition, a discretization method is presented to minimize memory requirements. Finally, the main conclusions are discussed in section V.

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II. State of the art

3D reconstruction of an underwater scenario is difficult but crucial in several areas. In 2010, a preliminary 3D mapping in an underwater scenario was presented based on the registration of six degrees of freedom [1]. The Tritech Eclipse sonar was used, which is a multibeam sonar with a beamwidth of 120º. Since the data is noisy, it was first necessary to use a pre-filtering technique. In order to achieve the reconstruction with the proposed method, three main steps were performed: the extraction of the planes, the pose registration by plane matching and finally the polygonization that finds the boundaries of each surface patch. Thus, it was possible to reconstruct an area without Inertial Navigation System (INS) or attitude using only 18 planes of a river flood gate. Another application related to underwater mapping is the inspection of caves. This is an important task because these structures are complex, confined and restrictive environments. Therefore, in [2] a robot was used with 3 types of sensors: navigation, acoustic sensors for remote sensing and mapping, and optical sensors for ground truth verification. A Mechanically Scanning Imaging Sonar (MSIS) was chosen as the main sensor for perception due to its 360-degree field of view. This sensor has as disadvantages that the reflected echo could have originated anywhere along the corresponding elevation arc and its low resolution. In this work, two MSIS are used simultaneously: one provides planar views of the environment for motion estimation through Simultaneous Localization and Mapping (SLAM); the other is used to capture the 3D shape of the cave and provides an understanding of the structure of the cave. In [3], a 3D reconstruction method was developed using data from a 2D multibeam sonar. The third component of the data is missing, causing some difficulties in interpretation. By observing the shadow behind the object, the elevation data can be determined (if the distance between the sensor and the object is maintained). In recent years, the use of MSIS for object reconstruction and detection has increased, but it is usually treated as a two-dimensional problem. Thus, a method has been proposed to reconstruct the shape of various submerged objects, and it has been proved that the ambiguity of this sensor can be solved by scanning the same object from multiple viewpoints [4]. Thus, probabilistic occupancy estimation is used with a new method that allows minimizing the fact of noisy and inaccurate MSIS measurements by efficient data structures. Recently, two different methods have been proposed to obtain 3D reconstructions of objects at short distances using large aperture imaging sonar [5]. The compared methods are based on blind deconvolution with a spatially varying kernel and nonlinear carving. Deconvolution provides more detailed maps, but is not iterative. Carving requires more computational memory but can build the map iteratively. Fusion of different sensor types is a solution to solve many problems, but it comes with some limitations. Therefore, in 2019, a method to extract 3D information by using two sonar devices was proposed: a forward scanning sonar and a profiling sonar, which allows full mapping of information [6]. The data from one sonar device can be converted to that of another, taking advantage of geometric constraints. The main strategy is divided into three steps: carving out the area without object with an occupancy grid, next predicting the elevation angle of the forward scanning sonar and finally performing the particle filter using the generated particles by calculating the weight and collected data of the forward scanning sonar. Nowadays, another important task is the problem of simultaneous localization and mapping in turbid water. For this reason, a novel approach was presented in which the main source of information is a Tritech scanning sonar and the ROV was also equipped with a depth sensor to provide an estimate of the 3D position of the vehicle [7]. In this work, a multi-stage pipeline was proposed for localization and mapping in shallow water with currents using a robot without inertial/odometry measurements. Thus, this method adopts a feature-based incremental smoothing and mapping solution, which includes three main steps: filtering some erroneous measurements, applying the SLAM algorithm, and performing accurate and robust Gaussian occupancy mapping.

III. 3D MAPPING

Creating a 3D reconstruction is a non-trivial task, as it depends on the application environment and the main goal of the reconstruction. To solve this problem, three main modules are usually used: one that captures perceptual information, one that is responsible for localization, and another that is the main module and allows the accumulation of information between the different modules. Nowadays, it is also important to think about the memory requirements, since they are very expensive for this type of application. This consideration is crucial, for example, in the cases where the data is collected and sent to a central system that creates the map and needs to send this information to the main vehicle so that it can make some decisions (without sacrificing the memory to do so).Therefore, there are already spatial data structures (octrees)[1], which allow to create the maps in an efficient and compact way. There are many approaches to solve the mapping problem with the acoustic sensors, but usually the occupancy grids are used because these sensors have an inherent uncertainty, namely due to the sensor model. In this way, the sensor readings can provide the information whether there is an obstacle in a scenario or not, using for this purpose which is the result of the fusion of the cumulative readings of a given position. This probability is updated along with the data acquisition and mapping process. In this way, some tools are already implemented and available in the literature using Occupancy Map approach in a 2D context or even for a 3D map. For example, it is possible to use the MATLAB Navigation Toolbox [2] or the Octomap library [3] in C++ [8]. Both implementations are useful tools, as they allow the construction of a map by assigning to each cell - independently - a probability indicating whether that cell is occupied or free [9]. In this way, the analysis of the final map is simple and more intuitive. Although the proposed method has already been implemented using both tools, in this work the MATLAB toolbox is used to demonstrate the results.

Therefore, in the next subsections, the required setup configuration is described and the data synchronization is explained (subsection III-A). Also, the main phases of the implemented procedure are detailed (subsection III-B).

A. *Setup configuration and data synchronization*

In order to test the developed technique, it was necessary to create a setup with systems that allow the aquisition of the data. Therefore, the main source of information is a Mechanical Scanning Sonar from Tritech, known for its configurable field of view up to 360º (where a larger field of view means slower data acquisition). In this case, the field of view was set to 30º, i.e. 15º for each side. This sensor has a low horizontal beam with (3º) and a high vertical beam with (35º). This fact implies that the reflected echo may have

[1]They have a tree data structure that can be adaptively subdivided to represent a shape, allowing a sparse voxelization of the data.

[2]https://www.mathworks.com/help/nav/mapping.html

[3]https://octomap.github.io/

originated anywhere along the corresponding elevation arc, which is considered as a disadvantage of this sensor. Moreover, the sonar has a minimum range of 0.3 meters and a maximum range of 75 meters. As mentioned earlier, another crucial module is the localization source to enable the appropriate point accumulation. In this case, the localization source was not the focus of the work and for this reason a previously built system based on tracking a visual ArUco marker was used. More specifically, above an experimental pool (4.4mx4.6m) there is a roof-mounted camera that captures images and uses an external system to identify and track the marker to obtain the x,y position and yaw orientation of the marker and consequently the sonar. In Fig. 1 the final setup can be seen, i.e. the sonar is attached to a platform in a horizontal configuration to be able to map the area under the sensor and the visual marker is attached to the surface of the platform to obtain the localization.

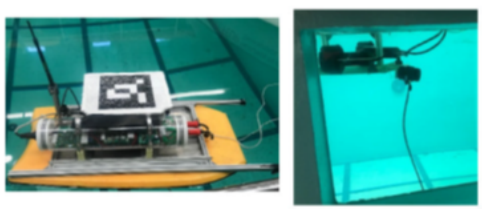

Fig. 1. Setup configuration for data acquisition.

The sonar and localization data are not synchronized because the frequency of the two pieces of information is very different (the sonar has an acquisition rate of 24 fps, while the localization data has 15 fps). Therefore, the timestamps of both information are compared, which means that each sonar sample is associated with the most appropriate value of positioning.

B. Point Accumulation

To solve this mapping problem, a point accumulation method was implemented. This technique can be divided into four phases, see Fig. 2.

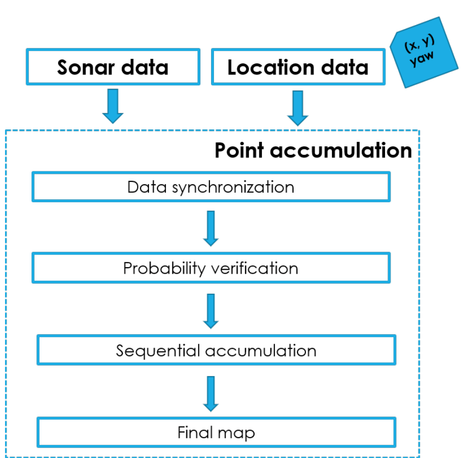

Fig. 2. Overview of the developed point accumulation method.

After both sensory information enters the system and the synchronization problem is solved, it is necessary to filter the sonar data, i.e., the artifacts caused by the sonar housing. Then the point accumulation is started, selecting the strongest bin of each tick. Knowing its 2D position (x and z) with respect to the sensor, one can assume that the arc of 35º is fully occupied, since the reflected echo may have originated anywhere. Nowadays, this approach is a common solution to this problem in state-of-art methods. However, this assumption implies a maximum error higher than the expected one (over 55 cm), which could lead to some errors in the prediction of the dimensions of the objects and their position. For this reason, in this work it was chosen to attribute a lower occupancy probability to the extremities of the arc than to the central part. Thus, this procedure eliminates about 40% of the whole arc, since the probability that the reflected eco is located in the central part is higher. Therefore, the correction was made to preserve only the central 20º of the arc. This adjustment improves the results as the maximum and constant error of the object dimensions decreases to 33 cm, which is a more feasible value, and consequently the error in the pose estimation of the objects also decreases to 15 cm. Next, two different checks were performed to ensure that the map is the most relevant:

- intensity - the main goal is to check if the intensity of the selected strongest bin is higher than a user defined threshold. Therefore, the bins with lower intensity values (less than 125 in a range from 0 to 250) are discarded, as their information is not considered relevant. This filter is always applied to all returned echoes.
- scan angle - this check allows assigning different probability values to each point depending on the corresponding scan angle. Therefore, the points corresponding to the scan angle of the extremities of the field of view have a lower occupancy probability than the points corresponding to the central angles. According to a previous study, the selected boundaries are chosen to cover more than 75% of the field of view, see Fig. 3. It is important to note that this filtering can be enabled or disabled depending on the object size, i.e., when reconstructing smaller objects, this filtering must be disabled to avoid deleting important data.

Fig. 3. Probability assigned to each sonar sample according to the scan angle when the sonar is configured with a scan angle of -15º to 15º.

It is important to note that these two checks reduce the final number of points in the reconstruction without loss of quality on the map. Table I shows the results of an experiment over the hull of a boat in terms of the number of points based on the two filtering methods. First, the intensity check reduces the final number of points a little. Using the intensity and scan angle checks simultaneously, one can see that the final reduction is more than 35% of the total points. In this way, it is not necessary to sacrifice the memory because the quality of the map is similar.

TABLE I
COMPARATIVE ANALYSIS OF THE NUMBER OF POINTS WITH AND WITHOUT THE FILTERING TECHNIQUES

Original	Intensity	Intensity & Scan Angle
4494	4095	2744

After all the testing procedures, the data can be accumulated. For this purpose, it is only necessary to bring the sonar data into the correct position provided by the localization module and thus into the world reference. In this case, the coordinates of an experimental pool are used as the world reference. An octree was used to accumulate the points, which can be used to efficiently create the final map. The chosen memory structure was created with a resolution of 100 cells per meter, which means that each cell is 1x1 cm. It was also determined that only those points with an occupancy probability greater than the standard toolbox threshold - 0.65 - should be included in the final map. Therefore, the final map is updated cyclically as new information is received to identify areas with obstacles closer to the sensor.

IV. Experimental Results

Developing a method for a real-world application is a really difficult task, as it needs to be tested in different ways, with different conditions and scenarios, to ensure that the method is able to achieve the main proposed objectives. Therefore, in the next sections, an evaluation related to building materials varying the gain parameter (subsection IV-A), some scenarios used to evaluate the proposed method (subsectionIV-B), and the main results related to the dimensions checked and observable shape (subsectionIV-C) are presented (subsection IV-C). The quality of the map obtained and some peculiarities of the method are also described. Finally, a discretization approach is presented which allows to reduce the memory requirements without losing the most important information (subsection IV-D).

A. Gain Experiments

When a robot navigates in an underwater environment with the main goal of inspection, it encounters different objects with different materials. So, in order to get a first sensitivity about the returned echoes in different materials, the first experiments were performed with the aim of comparing different values of gain. Thus, for 5 types of materials: wood, PVC, metal, concrete and plastic, the gain was varied between 30% and 60%, see Figure 4.

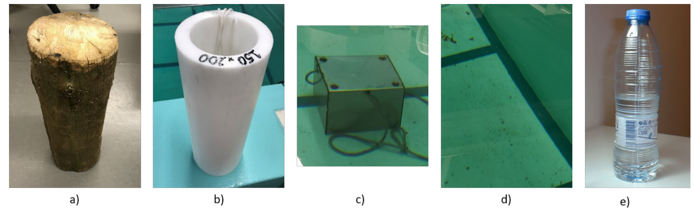

Fig. 4. The 5 material types used to evaluate the sensor: wood (a), PVC (b), metal (c), concrete (d) and plastic (e).

The plastic bottle is made of a material that does not give useful echo values, and this fact can be explained by the small thickness of the water bottle. The density difference between this material (when the bottle is filled with water) and the water is small, and therefore the echoes are absorbed and have no value too useful for any value of gain of the chosen interval. In contrast, the metal echoes return with higher values starting at a gain value of 20% (see Fig 5 a)). Figure 5 demonstrates the difference between the two objects: a metal box and a plastic bottle in the MSIS software. The metal box is visible from 20% of gain with good quality. The bottle is closer to the sensor, but the values returned at 20% of the gain parameter do not provide useful values (see Fig 5 b)). In an extreme test, with 70% of gain, the bottle is more visible, but there is a lot of noise and the scene is generally saturated (see Fig 5 c)). However, this type of plastic is not easily found in the sensor's field of view, and this is because when the bottle is filled with water, it floats, and when it is filled with sand or sediment, it is near the bottom (i.e., it will be similar to mapping deposited sediment).

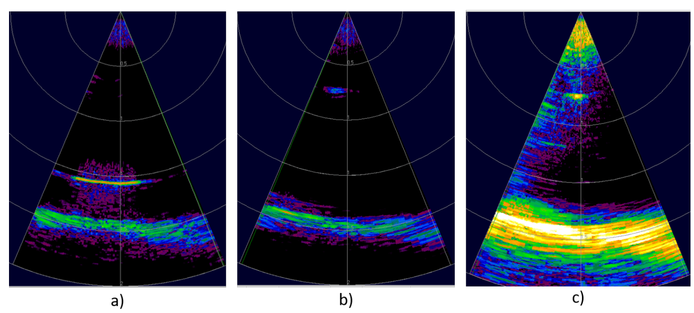

Fig. 5. Difference between the two objects: a metal box (a) and a plastic bottle (b) detected with a gain of 20% in the software of MSIS. In addition, a plastic bottle with 70% of gain is also shown.

In order to evaluate the sonar data and choose the best value in general, different values of gain are tested with different trajectories over the metal box, PVC cylinder, concrete, and the wood trunk. Table III summarizes the obtained results in terms of returned echoes during a mission with the driver of MSIS. The majority of the materials are well visible with 40% of gain. However, in order to choose a single value for all materials so that their visibility is not affected by the filtering techniques of the proposed method, a value of 50% of gain has been found to be most appropriate for these materials.

TABLE II
OBTAINED RESULTS IN TERMS OF RETURNED ECHOES VARYING THE GAIN PARAMETER

Material/Gain	30%	40%	50%	60%
Metal	[110,135]	[125,135]	[150,165]	[160,175]
PVC	[95,110]	[110,125]	[130,140]	[140,155]
Concrete	[90,130]	[125,140]	[130,150]	[140,155]
Wood	[105,115]	[125,145]	[135,160]	[165,180]

B. Scenarios

In order to test the developed method, it was necessary to collect some sets of localization and sonar data. Each data set consists of a file with the sonar data and the corresponding timestamp, and another file with the localization data and also the corresponding timestamp. To demonstrate and comment on the main results, different objects were chosen to prove the robustness of the method as well as some of its limitations. Thus, a metal box, a trunk of wood and a boat hull were chosen to verify if the method can correctly determine the dimensions of the objects and if it is possible to detect the shape of more complex objects and with non-straight shapes, see Fig. 6. In this way, in Table III are visible the scenarios used with these objects and some peculiarities of each.

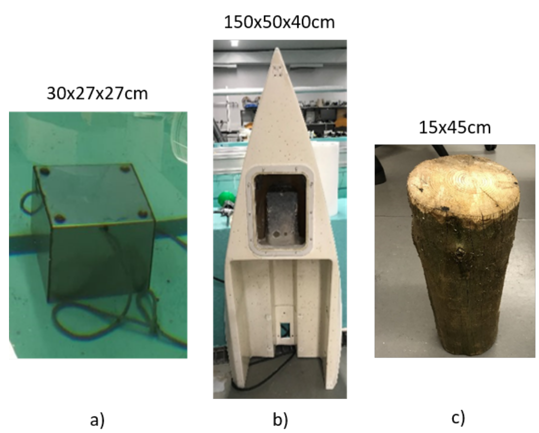

Fig. 6. Objects used to test the developed method: a box (a), a boat hull (b) and a trunk (c).

TABLE III
THE SCENARIOS USED TO TEST THE DEVELOPED IMPLEMENTATION

Objects	Scenario	Trajectory	Velocity
Metal box	A	y direction	0.08m/s
	B	y direction	0.13m/s
Trunk	C	y direction	0.03m/s
Hull of boat	D	x direction	0.04m/s
	E	x and y direction	0.05m/s

C. Mapping effectiveness

The first experimental test (scenario A) was performed with a metal box, since it allows to check the dimensions of the straight objects. As for the obtained positioning, the successive samples are correct and well referenced with respect to the experimental pool. The yaw orientation had to be filtered since the successive values show many inconsistencies, as can be seen in Fig. 7.

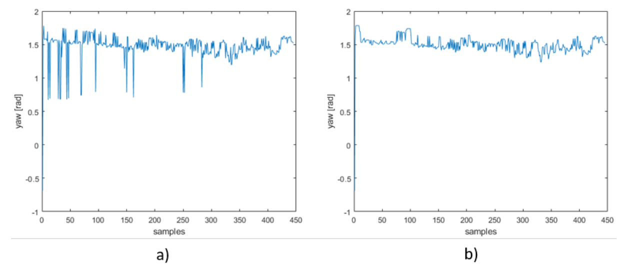

Fig. 7. The original yaw angle a) was filtered to ensure consistency along trajectory b).

Regarding the accumulation points, it is crucial to point out that the scan angle filter was disabled since the metal box is small and it is crucial not to delete important data. The dimension in the direction of motion (y) obtained directly by the method is 59 cm. As explained earlier, due to the assumption that the vertical arc of the sensor occupies more than one point, there will always be an error in the direction of the predominant motion. In this implementation, it is assumed that only the central part is occupied, since the probability of this occurrence is higher. Thus, the detected dimension of the object in the y-direction has a constant deviation of 33 cm. Thus, in this direction, the proposed method detects a box with 26 cm. On the other hand, in the other directions (x and z directions), this assumption is not necessary. The obtained dimensions are well estimated with an error of less than 5 cm for the width, length and height of the object, as can be seen in Table IV.

TABLE IV
DIMENSIONS OBTAINED OF THE METAL BOX IN SCENARIO A

Scenario A	x dimension	y dimension	z dimension
Method	23cm	26cm	25cm
Original	27cm	30cm	27cm

The second test with the metal box (scenario B) shows similar results to the previous one. It is important to point out that the speed of the acquisition data is crucial and changes the results obtained, since this set is acquired at a higher speed and for this reason only two scans represent the surface of the box. In this way, although the dimensions are correct, it is difficult to detect, for example, the shape of the object when the speed is high.

The reconstruction performed over the wood trunk with scenario C allows to see that the existence of the object, see Fig. 8, located above the ground of 45 cm. This measurement is correct because the trunk was 15 cm of thickness, but this object fluctuates above 30 cm of the bottom of the experimental pool.

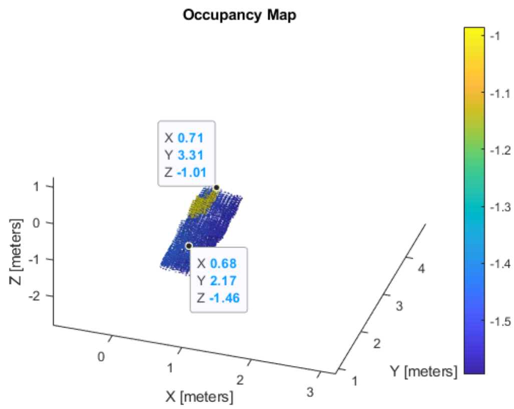

Fig. 8. Final map of the surface of the trunk and the dimensional verification in terms of height.

The dimensions estimated by the method in terms of x and y are correct, as can be seen in Table V. It is critical to note that the scan angle filter was also disabled in this test.

TABLE V
DIMENSIONS OBTAINED OF THE METAL BOX IN SCENARIO C

Scenario C	x dimension	y dimension
Method	20cm	42cm
Original	15cm	45cm

Scenario D was performed over the surface of the boat hull and allows to see that the complex shapes are visible in the final map. To create the map of this object, the scan angle filtering is enabled because the hull of the boat is larger than the others and therefore it is possible to keep the shape of the boat on the map without affecting the memory cost with a higher number of points. As can be seen in Fig. 9 (top), the shape of the hull is well created and it is visible that there is a funnel part and a larger part. As for the dimensions, it can be noted that the length of the mapped boat is well estimated (1 m, considering the maximum error of 33 cm), see Fig. 9 (bottom). Therefore, it can be noted that the boat is not fully mapped in terms of length and width (only 40 cm), since the survey carried out deviated from the center of the boat.

The last experiment (scenario E) was performed with a change in direction with respect to the x and y motion and the filtering of the scan angle is also enabled. As can be seen in Fig. 10 (top), the funnel shape of the boat is visible in the final reconstruction, as well as, the largest part. The blue zone is the bottom of the experimental pool that is about 1.5 meters from the sonar, which is correct information since the pool has a height of 1.70 meters and the sonar is over 20 cm from the surface. With respect to the y-coordinate, it can be seen in Fig. 10 (bottom) that the estimated coordinates are correct, since the map has about 40 cm in the largest part and 23 cm in the funnel part. There is a small error in the largest part (7 cm), which could be explained by a deviation in the localization method or even in the filtering technique.

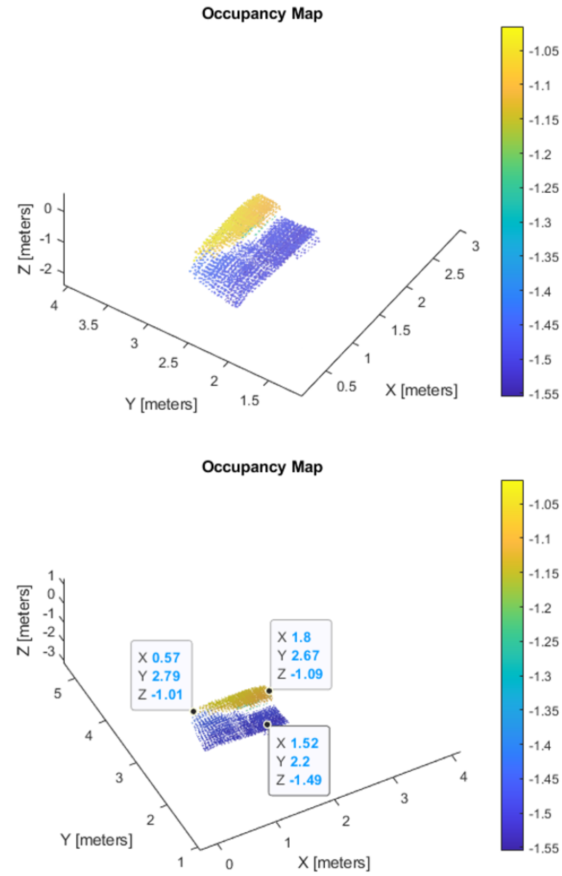

Fig. 9. Final map showing the shape of the hull (top) and the dimensional verification in x and z coordinates (bottom).

As for the length (x-coordinate), it is correct because we can see that it is about 1.5 meters (after subtracting the maximum possible error of the method), which corresponds to the true measurement.

D. Discretization

Sometimes, in real applications, it may be necessary to send only the points of the fixed grid to the control module. Therefore, in order to test this function, it was necessary to binarize the obtained map in terms of x and y coordinates, with different step sizes (cm). With respect to the heights, the original values, i.e. the sonar measurements, are kept. Table VI shows the number of points for the tested step sizes for scenario E, which has an original number of 10318 points.

TABLE VI
THE NUMBER OF POINTS AFTER THE DISCRETIZATION PROCESS FOR SCENARIO E

Step size (cm)	Number of points
1	7664
3	2789
5	1125
10	465

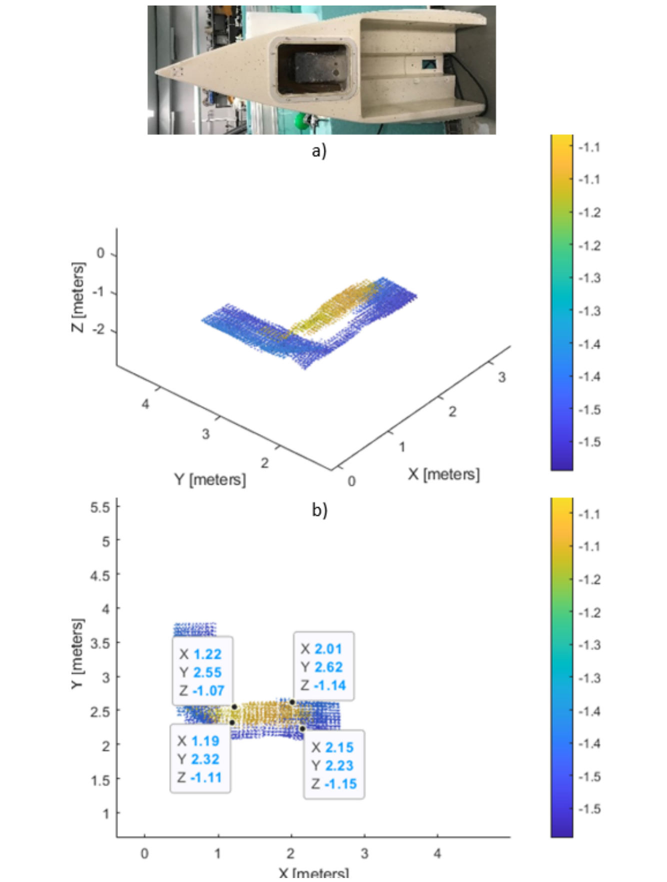

Fig. 10. Final reconstruction of the scenario E (top) and checking dimension in terms of y coordinate - width of the boat (bottom).

From this table, it can be seen that the total number of points is greatly reduced, which can be a good feature for real-world applications since the final map retains the shape of the objects. The step size depends on the application of the final reconstruction and must be chosen by the user. In Fig. 11, the obtained map can be seen with a step size of 5 cm.

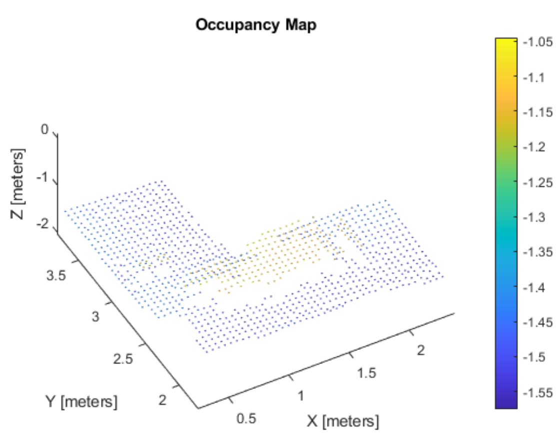

Fig. 11. Discretization process applied to scenario E with a step size of 5 cm.

The selected step size is sufficient to reduce the memory requirements for the vehicle (about 90%). Moreover, good results are visible in terms of represented shape without information loss. Sometimes a small error (of the order of cm) can be seen when checking the dimensions, since this method is an approximation of the real map in terms of x and y coordinates.

V. Conclusion

In this work, a simple method has been developed to obtain a preliminary version of a 3D reconstruction of the scenes under the sensor using an external source localization and octrees. Thus, it is possible to evaluate the performance of MSIS in this type of mapping task and to detect that objects are close to the robot. One of the most important feature of the method is that it performs two different filtering techniques: one according to the returned intensity and another according to the scan angle (which can be switched off). Moreover, unlike the usual techniques, only the central part of the 35º arc of the sensor is considered occupied (about 20º). These techniques allow to reduce the memory consumption when creating the map without losing important information. Thus, from the obtained results, it can be concluded that:

- On the experiments with various materials: most of the materials tested are well visible with 40% of gain. However, in order to choose a single value for all materials so that their visibility is not affected by the filtering techniques of the proposed method, the authors considered a value of 50% of gain to be most appropriate.
- If only the central part of the arc is occupied, the constant error in the measurement dimension of the direction of motion is reduced to 33 cm (instead of 55 cm).
- The method allows to map smaller objects with straight lines without resorting to the scan angle filter. The estimated dimensions in the final map have a maximum error of 5 cm, which is a good result for real-world applications.
- The developed techniques show that it is possible to observe objects with more complex shapes and to create maps with trajectories with directional changes. For larger objects, it is possible to manually activate the filtering of the scan angle, reducing the number of total points. It is also important to point out that a more correct estimate of the positioning contributes to a better mapping of a scene.
- The z-dimensions of the objects are correct and the MSIS shows that it is suitable for this type of survey, with the main goal of finding the obstacles closer to the sensor.
- The survey speed proves to be important, as some information is lost in faster trajectories. On the other hand, the configuration of the scan angle can also reduce the quality of the final map, because the larger the field of view, the slower the rotation speed of the sensor head. Thus, a balance between the field of view and the speed of the vehicle must be achieved.

- Finally, performing a discretization process with different step sizes shows that it is possible to achieve a simpler representation of the scene, able to collect some information about the objects and with less memory cost. This process is crucial, for example, in the cases where the data is collected and sent to a central system that creates the map and needs to send this information to the main vehicle so that it can make some decisions (without sacrificing memory for it).

For future work, the authors will conduct new experiments with new objects with different properties and building materials. The acquisition conditions need to be diverse (namely in muddy and diffuse waters) to simulate more and more the challenges that occur, for example, on a dam. Moreover, the authors want to improve the proposed method to automatically decide when to use the scan angle filter. Moreover, it is important to test some techniques that can improve the quality of the final representations obtained from sonar data with occupancy grids to overcome the inherent limitations. Together with new intended improvements, the goal is to obtain a reduced computational cost for applying and implementing the method in a real context using the C/C++ language.

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