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Extraction of 3D Object Signatures from Images Obtained from Sonar Fitted on AUV

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ABSTRACT

Autonomous Underwater Vehicles are important tools for monitoring the underwater environment. Imaging SONAR provides two dimensional images which contain range and bearing of the detected slice. In order to have the complete information of the object, the signature in all three dimensions is required. Therefore these images have to be processed to extract the 3D signature of the object. In order to identify the object, size and shape are important aspect along with the depth information of object. Since a 2D image does not contain the depth information, it needs to be extracted. In this paper an algorithm has been presented to extract the 3D signatures of the objects from the 2D images received from SONAR. The algorithm developed is based on the slice centroid calculation and integration of boundary points of 2D image slices obtained at various fixed depth intervals. The algorithm is tested on the real time images of the objects in Bay of Bengal, captured by the sonar fitted on AUV.

Keywords- **Two Dimensional, Three Dimensional, AUV, Sonar, Boundary points, Centroid.**

I. INTRODUCTION

An Autonomous Underwater Vehicle (AUV) is a robot which travels underwater for the purpose of surveying. The use of AUVs is therefore to study lakes, ocean, and the ocean floor. A variety of sensors can be mounted on AUVs to measure the concentration of various elements or compounds, the absorption or reflection of light, and the presence of microscopic life. Sonar is a Sensor/technique that uses sound propagation, mounted onto the AUVs to navigate, communicate with or detect underwater mines. Sonar information collected while searching for, or identifying, underwater mines is often presented to the operator in the form of a two dimensional image. This 2D information provides only range and bearing but not depth of the target. Those 2D systems cannot distinguish between the safe sea floor and the dangerous in-water obstacle through depth measurement. They must rely on visual cues to guess whether or not the obstacles are located in the water column or on the sea floor. This is a result of the three-dimensional nature of the search domain and the human use of vision as the primary source of sensory information. The heavy human reliance on visual information

has made human beings highly skilled at the detection and classification of objects in images. Despite human expertise at comprehending visual information, sonar imagery still presents many challenges since it lies outside the normal scope of human visual experience. In this paper, the input consists of the signatures of the objects detected in the images provided by a Sector Scan Sonar. System output is a full 3D model extracted from 2D image. The output is also provided in the form of signature on the similar line of 2D objects. Only difference is that here it is a matrix where rows indicate the angle Theta and column indicate the angle Phi and the elements in the matrix indicate the radial values at these angles. In the case of camera we can easily obtain the 3D images from the 2D pictures, only condition being that the pictures be taken from different angles, whereas with respect to Sonar images the condition is entirely different. The sonar gives frame by frame image in which the object is not directly obtained as in camera pictures and the frame may have more than one object [1]. So by following some image processing techniques the objects are identified. The images in both the cases are also not the same as the same will be evident from the subsequent paragraphs. The processing of sonar data can be broken into two domains. The first domain is the use of signal processing (mostly one-dimensional) techniques to enhance the creation of sonar imagery. For example, the use of adaptive beam forming techniques to enhance the contrast of embedded objects in sonar imagery lies in this first domain. The second domain is the use of image processing (two or higher dimensional) techniques on sonar imagery to aid or automate the detection and classification of embedded objects.

II. THREE DIMENSIONAL GEOMETRIC MODELS

This is geometric model of the physical universe related to the three-dimensional space. These three dimensions are length, width, and depth (or height), in fact any three mutually perpendicular directions can serve as the three dimensions. 3D geometrical models represent a 3D object using a collection of points in 3D space, connected by various geometric entities such as triangles, lines, curved surfaces, etc. being a collection of data (points and other

information), 3D models can be created by hand, algorithmically (procedural modeling), or scanned. 3D models represent a 3D object using a collection of points in 3D space, connected by various geometric entities such as triangles, lines, curved surfaces, etc [2]. Being a collection of data (points and other information), 3D models can be created by hand, algorithmically (procedural modeling), or scanned. 3D models are widely used anywhere in 3D graphics. Actually, their use predates the widespread use of 3D graphics on personal computers. Many computer games used pre-rendered images of 3D models as sprites before computers could render them in real-time.

Today, 3D models are used in a wide variety of fields. The medical industry uses detailed models of organs. The movie industry uses them as characters and objects for animated and real-life motion pictures. The video game industry uses them as assets for computer and video games. The science sector uses them as highly detailed models of chemical compounds. The architecture industry uses them to demonstrate proposed buildings and landscapes through Software Architectural Models. The engineering community uses them as designs of new devices, vehicles and structures as well as a host of other uses. In recent decades the earth science community has started to construct 3D geological models as a standard practice.

Advantages of 3D over 2D

3D effects are often achieved without modeling and are sometimes indistinguishable in the final form. Some graphic art software includes filters that can be applied to 2D vector graphics or 2D raster graphics on transparent layers.

Advantages of 3D modeling over 2D methods include:

- Flexibility, ability to change angles or animate images with quicker rendering of the changes;
- Ease of rendering, automatic calculation and rendering photorealistic effects rather than mentally visualizing or estimating;
- Accurate photorealism, less chance of human error in misplacing, overdoing, or forgetting to include a visual effect.

III. Reconstruction of 3D Object from 2D Images of Sonar

There are many different types of marine sonars in use today. Some sonars use one narrow, downward-looking beam, such as depth-sounders and fish finders. Others only look at a narrow slice of water and are called 2D sonars. Examples are Sidescan Sonar, Sector Scan Sonar and small craft navigational sonars [5]. The results of these type of Sonar's is obstacle detection and avoidance, however, they require continuously updated range, bearing, and depth information on all of the underwater hazards in front of the vessel. Sonar displays a new 2D underwater map frame by frame, and provides mariners with a major advancement in obstacle avoidance and navigation technology. These Sonars provide the user only two of the components and they are range and bearing. They do not provide depth, and in shallow water, they do not provide navigationally useful information. Even though the 3D-Sonar provides all three navigationally significant components: range, bearing, and depth it has a disadvantages that it is expensive than 2D Sonar and depth is only estimated at the height of the sonar sensors. In order to reduce the cost of using this 3D sonars, 2D sonars are generally used in obstacle avoidance and navigation technology. Even though these 2D sonars provide the user two of the components needed that is range and bearing [3]. They do not provide depth. In order to know the depth of the obstacle using 2D sonar we have to obtain the 2-Dimensional images of the obstacle at different levels of the Sonar, and by applying image processing techniques to these 2D images the unwanted data like noise, reverberations etc is eliminated. The 2D images of the object are taken at different levels of the sonar and are used to reconstruct the 3D object of the obstacle in order to find the shape and size of the obstacle using 2D sonar. There can be two conditions one in which the Sonar beam partially covers the object, and the second in which Sonar beam covers the complete object.

A. Algorithm for extraction of 3D information from SONAR Underwater Images

Sonar beam partially covers the object

The Fig. 1 explains the case when the sonar beam does not covers the object completely. Fig. 1(A) to 1(D) gives the step by step illustration about the Reconstruction of 3D object from 2D images given by the DST Sonar. First the SONAR gives the raw images by scanning a target (3D) as shown in Fig. 1(A).

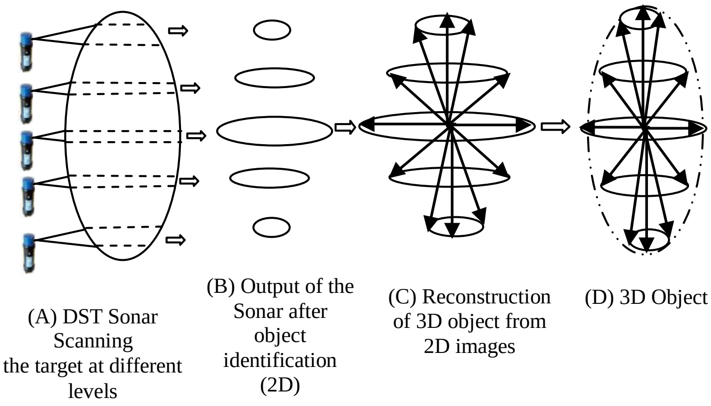

Fig. 1 Schematic view of reconstruction of 3D object from 2D images of a DST Sonar

Sonar information collected while searching for or identifying, underwater object is often presented to the

operator as two dimensional (2D) raw images. These images along with the desired object contains noise, reverberations etc. To identify the object the unwanted data must be eliminated. Towards this image processing techniques like segmentation, edge detection etc. are used and the noise, reverberations etc. are removed. Now the object is identified which is in 2D. Since one image is not sufficient to construct a 3D object, some more raw images of the same target are taken by moving the AUV up and so as to cover the complete object. Once the complete scanning is done there are number of slices which are available and they are sufficient enough to construct the three dimensional picture of the object.

Fig. 1A shows the scanning of the target at different levels. Fig. 1B shows the output of SONAR at every level of scanning. Fig.1C shows how the 3D object is reconstructed and finally Fig. 1D shows the 3D object.

Sonar beam covers complete object

In the previous case we have discussed the case wherein sonar beam partially covers the object but in case if sonar beam covers complete object (that is size of the obstacle is less than Sonar beam width), then the output of the sonar will be a single 2-Dimensional image as shown in Fig.2.

In this case also, it is not possible to get any three dimensional information from this single image, as minimum two views are required to have the depth information. In this case also some more images of the same target are taken by moving the sonar up and down so as to scan the object at different levels as shown in Fig 2 and processed [4]. Hence the Sonar has to move up and down so as to give the various 2D images of the object, and obtaining these 2D images at different levels and these images are then used to reconstruct the 3D object. Fig. 3 illustrates the scanning of the object in this particular case.

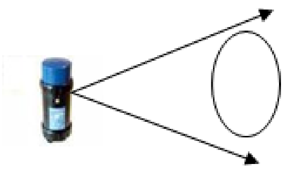

Fig. 2 The Sonar beam covers complete object, (that is size of the obstacle is less than Sonar beam)

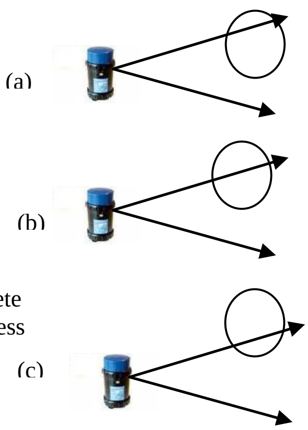

Fig. 3 The Sonar is moved down to scan the obstacle

Proposed 2d to 3d Sonar Image Algorithm

Slices of the obstacle information with different radii at different levels are considered as input to the algorithm.

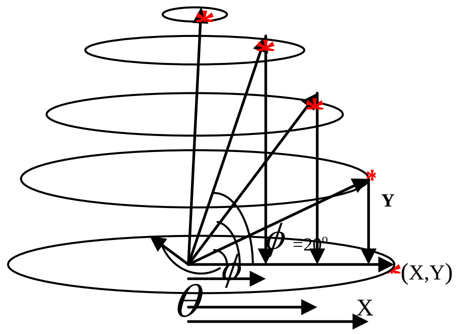

Fig. 4 Schematic view of Construction of Sphere from Slices.

Here coordinates of the slice are X, Y and the level of the slices represents the Z-coordinate. The parameters those are needed to uniquely describe the position of a point are the azimuth θ, altitude ϕ and the distance R from the point of origin. From these parameters 3D shape can be reconstructed by fixing the angle θ in one direction and by varying another angle ϕ in another direction. The azimuth (θ) is an angle made with X axis connecting given point and the origin of the coordinate's axis and altitude ϕ is an angle varies from 0^0 to 360^0 (with an interval of 10^0).

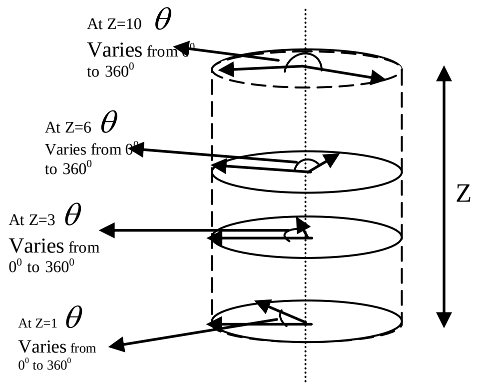

Fig 5 Schematic view of Construction of Cylinder from Slices

The steps involved in the proposed algorithm are given below.

The slices with different radii are considered (see in Fig. 4 for Sphere and see in Fig. 5 for Cylinder).

$$z = r \times \cos\theta \qquad \textbf{(1)}$$

Where, θ = azimuth angle made with X axis connecting given point and the origin of the coordinate's axis
z is the position that is level of the slice.

$$Z = \sum_{i=1} Z_i \quad (2)$$

$$Z = [Z_1, Z_2, Z_3 ....Z_n] \quad (3)$$

And thus by calculate the distance $x_1, x_2, x_3 .... x_n$ by the formula

$$X = Z \tan\theta \times \cos\phi \quad (4)$$

Where, ϕ = angle variation in altitude and varies from 0^0 to 2π (with an interval of 10^0)
For different values of θ and ϕ at different levels of Z, x value is calculated using the Eq. 3 and stored in an array X.

$$X = \sum_{i=1}\sum_{m=1}\sum_{n=1} Z_i \times \tan\theta_m \times \cos\phi_n \quad (5)$$

$$X = \sum_{i=1} X_i \quad (6)$$

$$X = [X_1, X_2, X_3 ....X_n] \quad (7)$$

Obtain the different values of X for each value of ϕ. Using x and ϕ values compute 'y' using Eq.7.

$$y = x \tan\phi \quad (8)$$

For different values of x andϕ, y value is calculated using the equation 7 and stored in an array Y.

$$Y \sum_{i=1}\sum_{m=1} X_i \times \tan\theta_m \quad (9)$$

$$Y = \sum_{i=1} Y_i \quad (10)$$

$$Y = [Y_1, Y_2, Y_3 ....Y_n] \quad (11)$$

IV. RESULTS FOR 3D CONSTRUCTION OF UNDERWATER IMAGE

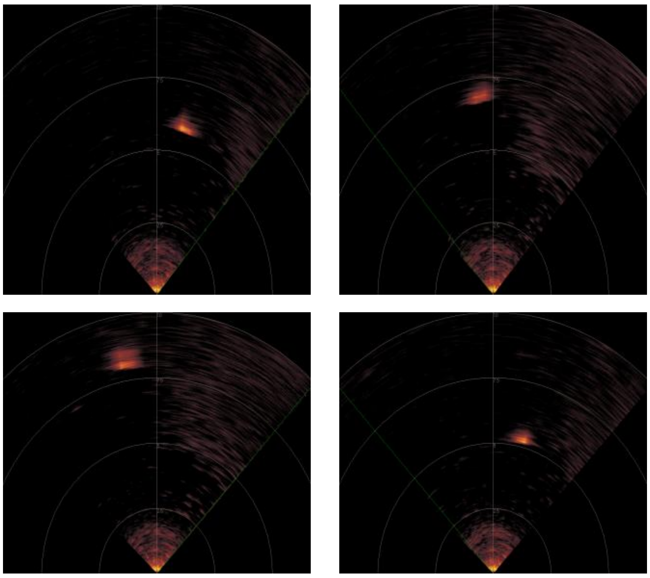

Fig. 6 2D Underwater SONAR images

The Fig. 7 represents the reconstruction of 3D irregular underwater images from the 2D slices obtained from Chirp

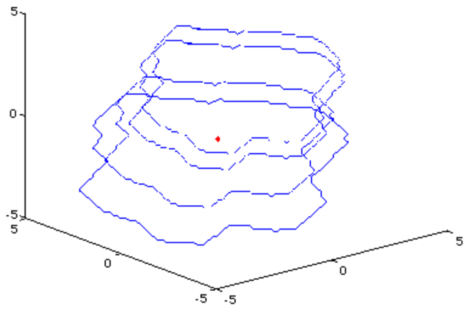

Fig. 7 3D model of Underwater SONAR images

technology SONAR Fig. 6. Here coordinates of the slice are X, Y and the level of the slices represents the Z-coordinate.

The parameters are needed to uniquely describe the position of a point. These parameters are the azimuth θ, the altitude z. From these the 3D shape is obtained by fixing the altitude z and by varying angle (θ) varies from 0^0 to 360^0 (with an interval of 10^0). The azimuth (θ) is an angle made with X axis connecting given point and the origin of the coordinate axis and altitude z varies at different levels. After reconstructing the complete 3D model of irregular underwater image is shown in Fig. 7.

V. CONCLUSION

In order to extract the 3D signature of the objects using imaging SONAR, the 2D images taken at various depth along Z axis at fixed intervals have been processed. The first step in the developed algorithm is to arrange the 2D images in a stack followed by the calculation of the centroids of each slice. These centroids along with the centroid of the centre slice forms the core of designed algorithm. The boundary points of the slice represents (X, Y) coordinates and the depth location represents by the Z-coordinate. These X, Y and Z parameters are then taken and along with the calculated centroids a 3D signatures formed in terms of θ, ϕ and R. The signature of the object is finally defined by fixing the azimuth angle for different values varied from 0^0 to 360^0 and for each value of azimuth angle, ϕ is varied from 0^0 to 360^0. While extracting the 3D signatures, two specific cases have been considered in developing these algorithms. In the first case beam covers the complete object and in the second case the beam partially covers the object. The 3D model has been developed in respect of both the cases. The developed algorithm has also been tested for extraction of the 3D

signatures from the 2D images received from the sonar in real time environment and observed to be working satisfactorily.

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REFERENCES

1. **Maciej Borkowski, "2D to 3D Conversion with Direct Geometrical Search and Approximation Spaces", University of Manitoba, 24 August 2007**
2. **Silva and C.A. dos S, "3D Motion and Dense Structure Estimation: Representations for Visual Perception and the Interpretation of Occlusions" Institution Superior Tecnico, Universidate Technica de Lisboa, Spain, 2001.**
3. **Atick, P. Griffin, and A. Redlich. "Statistical approach to shape from shading: Reconstruction of three-dimensional face surfaces from single two-dimensional images". Neural Computation, 8(6), 1996, PP:1321–1340.**
4. **Daniel E. Huff , "Surface Ship Location Based On Active Sonar Image Applied Research Laboratories", The University of Texas at Austin Literature Survey EE 381K-14 Multidimensional Digital Signal Processing March 25, 2005.**
5. **I. Tena Ruiz, Y. Petillot, D. M. Lane, C. Salson "Feature Extraction and Data Association for AUV Concurrent Mapping and Localisation" Proceedings of the 2001 IEEE International Conference on Robotics & Automation Seoul, Korea, May 21-26, 2001.**