3D Surface Generation for Riverbed for Recce Operations

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Abstract - *The system provides a detailed real-time three-dimensional view of the underwater beds using the data collected by the echo sounder, a Dual Global Positioning System, and a heading sensor on a remote-controlled boat. It plots a graph as per the coordinates collected across a wide range of depths. It aims at mapping most of the underwater bed profile generation to aid the surveying for military bridging. This system uses the technology of Multi-Beam Sonar, making it far more efficient and accurate compared to the primitive method of knotted ropes. A Human Machine Interface will generate an interactive three-dimensional surface of the surveyed area.*

Key Words: Echo Sounder, Human Machine Interface, Military Bridging, Three-Dimensional Surface

1. INTRODUCTION

The system typically can be used for hydrographic surveys to determine the depth of water and the nature of the seabed. The coordinates generated can be transformed into river bed depth to create a depth map. The software utilizes the collected data set for plotting and three-dimensional visualization of the underwater bed profile. These visuals of the river bed can enable us to explore the wide ranges of altitudes and depths for better navigation.

Military bridge inspectors usually have to find out what lies underneath the surface of the rivers. Thanks to new echo sonar inspection technology, the bridge inspectors now possibly have a way to see previously hidden riverbed floors and underwater bridge structures in far better detail than ever before.

Typically, bridge engineers prefer professional divers to provide information about what is underwater. But diving inspections don't always give precise information about bridge damage, debris, and riverbed topography.

All the bridges that span waterways require underwater inspection.

In recent years, bridge inspectors shifted to underwater inspection technologies to know areas of interest and direct divers who can inspect hands-on. In turbid, sediment-heavy conditions with low visibility rivers, non-optical technologies – laser, radar, and echo sounder – offer safe and helpful options. Echo sounder collects underwater acoustic data into point clouds for imaging two- and three-dimensional models of conditions [1].

2. SURVEYING

Hydrographic Surveying delivers a detailed underwater inspection, visually and numerically describing shapes of the seafloor or river beds. Typically surveying boat uses single-beam units for shallower water surveys combined with land survey data that can be collected by drone.

Bathymetric surveys can be utilized for dredging, coastal process, the environment, ports, reservoirs, harbors, rivers, lakes. This information can be used to generate charts & maps, contours, volumes, cross-sections, long sections, 3D surfaces, and fly-throughs.

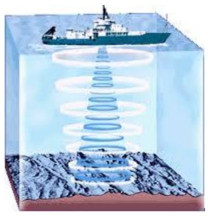

Fig -1: Simple Sonar

By using simple sonar, oceanographers can determine the depth of the ocean floor in a particular area.

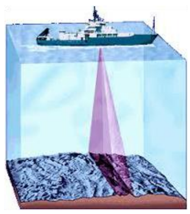

Fig -2: Modern Multiple Beam Sonar

Modern multi beam sonar obtains a profile of a narrow swath of seafloor every few seconds.

3. DATA REPRESENTATION

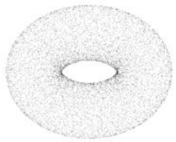

Fig -3: Simple Sonar

A point cloud is a collection of data points in space. The points represent a three-dimensional shape or object. Each point has its collection of X, Y, and Z coordinates. Point clouds are typically produced by three-dimensional scanners or by photogrammetry software, which measures several points on the external surfaces of objects around them.

4. DATA PREPARATION

To construct the topography of riverbed using three-dimensional point cloud data the approach consists of data cleaning and mapping to a matrix [2].

I. Convert the latitude and longitude values to fill the grid values

II. Get the minimum value from latitudes and longitudes

Say minlat and minlon, we will consider (minlat, minlon) as our origin (0, 0).

III. Loop from i = 0 to n:

$X_{(i)}$ = abs(minlat – latitude$_{(i)}$)
$Y_{(i)}$ = abs(minlon – longitude$_{(i)}$)

IV. The Resultant matrix will look like this:

Table -1: Resultant Matrix

A_{00}	**A_{01}**	**A_{02}**
A_{10}	A_{11}	A_{12}
A_{20}	A_{21}	A_{22}

Where,
A_{nm} is the depth value corresponding to the x and y value.

5. DATA PROCESSING

*I. Approach 1 (Using 3*3 matrix average):*

Fill the matrix boundaries with zeros to normalize the average calculation as follows:

Table -2: Resultant Matrix

0	**0**	**0**	**0**	**0**
0	A_{00}	A_{01}	A_{02}	0
0	A_{10}	A_{11}	A_{12}	0
0	A_{20}	A_{21}	A_{22}	0
0	0	0	0	0

Loop from i = 0 to n,

If value at i > 0,

Average at x, y = [(x-1, y-1) + (x, y-1) + (x+1, y-1) + (x-1, y) + (x+1, y) + (x-1, y+1) + (x, y+1) + (x+1, y+1)] / number of non-zero values.

Set,

(x, y) = Average at x, y.

Else, continue the next iteration.

The iteration in the program takes $O(n^2)$ execution time and lookup will take O(1) time. So, the overall time complexity of the algorithm will be $O(n^2)$. Due to high data density the algorithm may not be reliable.

II. Approach 2 (Linear Interpolation):

It fills the values by calculating the midpoint from the previous and next values. If missing,

(x, y) = ((xprev + xnext) / 2, (yprev + ynext) / 2)

Else, continue.

The linear interpolation algorithm takes constant time to compute and fill missing values.

4. THREE-DIMESIONAL SURFACE CONSTRUCTION

The surface construction phase solves the problem of reconstructing a three-dimensional surface using the cleaned data set obtained in the previous stage.

Many algorithms are proposed for surface reconstruction [3], [4], and [5] while the meshing algorithm is adopted in this paper is Polygon Triangulation [6] which is a method of constructing a surface from a two-dimensional array of points. The significant advantage of this algorithm is that it provides a simple, and efficient method for constructing a water-tight surface without calculating Euclidean distances between the points.

The algorithm loops through the mesh's Positions collection to see if the desired point is already there. If it is, the method returns the point's index in the set. If the point isn't there, the function adds it and returns the new point's index.

As the triangles reuse existing vertices, they share any vertices they can. The result is a smooth surface.

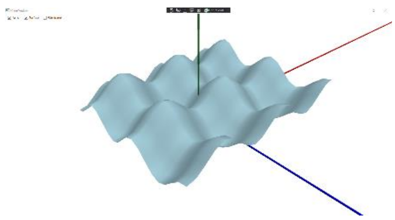

Fig -4: Smooth Three-Dimensional Surface

5. SPATIAL INTERPOLATION

After reconstructing a smoother surface, we further explored some of the methods (Spatial Interpolation) [7] for overlaying a shaded altitude map over it.

Spatial interpolation is interpolation on functions of more than one variable; when the variates are spatial coordinates, it is also known as multivariate interpolation.

It is particularly important in geo-statistics, where it is used to develop a digital elevation model from a set of points on the Earth's surface (for example, heights in a topographic survey or depths in a hydrographic survey).

The depth model uses color to indicate water depth. Our approach is straightforward, colors on the "warm" end of the spectrum – red, orange, and yellow - depict shallower water. As the water deepens, the colors shift through green, blue, and eventually into violet. Dryland is usually shown in white.

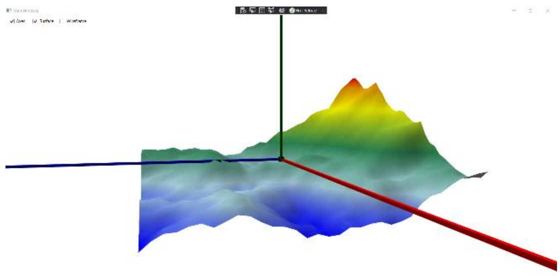

Fig -5: Water Depth Overlay On 3D Surface

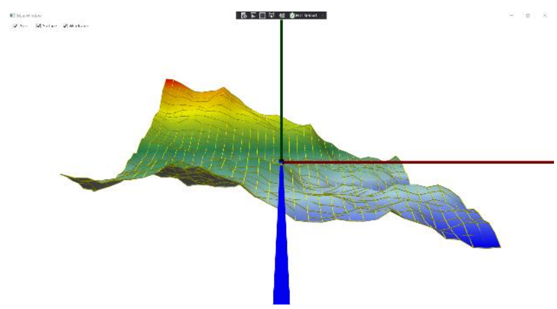

Fig -6: Water Depth Overlay on 3D Surface with Wireframe Enabled

6. CONCLUSION

The system follows an efficient approach to reach the objective of mapping water body mounts and generating profiles. It has various practical and research-based applications.

ACKNOWLEDGEMENT

It gives us pleasure to be a part of DRDO and working on Project of '3D Surface Generation for Riverbed for Recce Operations'.

Firstly, we would like to express our indebtedness appreciation to our External & Internal guide Mrs. Neerja M. Thakur & Prof. U. C. Patkar. Their constant guidance and advice played very important role in making the execution of the Project. They always gave us their suggestions, that were helpful in making this paper as flawless as possible.

We would like to express deepest appreciation towards Dr. R. N. Patil, Principal, Bharati Vidyapeeth's College of Engineering, Prof. U. C. Patkar, Head of Department of Computer Engineering and Project Co-ordinator whose invaluable guidance supported us in completing this paper.

At last, we must express our sincere heartfelt gratitude to all the staff members of Computer Engineering Department who helped us directly or indirectly during this course of work.

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