DESIGN AND DEVELOPMENT OF A WEB-BASED PLATFORM FOR THE MODELLING AND VISUALIZATION OF BATHYMETRIC DATA

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ABSTRACT

Bathymetric exploration plays a crucial role in the development of the blue economy, which encompasses sustainable use of ocean resources for economic growth, improved livelihoods, and ocean ecosystem health. Bathymetric data collected using sonar systems are usually represented as bathymetric charts. The interactive visualization of bathymetric data is essential for understanding underwater terrain features and their spatial distribution. This paper outlines the design and development of an interactive web-based platform for bathymetric surface model generation from XYZ point sonar data of entire coastal Kerala. The platform also facilitates orthographic and perspective visualization of surface models. Several functionalities such as profiling and volumetric change analysis were developed. PostgreSQL with a spatial extension was used to store the bathymetric data. The back-end computing was achieved using python flask. The front-end was implemented using web technologies such as HTML, CSS and JavaScript. The integration between the front-end, back-end and the database was achieved through RESTful APIs. This web-based platform provides a comprehensive and up-to-date information on bathymetric survey charts published by Hydrographic Survey Wing. This portal allows the user to search and view bathymetric visualization overlaid on a map and details of coastal features, Tide, Water quality parameters and coastal protection structures. This portal facilitates decision making in coastal engineering, environmental monitoring, coastal zone management, navigation safety and marine habitat mapping, etc.

Keywords: Bathymetric, Coastal Engineering

1. INTRODUCTION

Bathymetry, which involves measuring water depths in oceans, rivers, and lakes, is fundamental to understanding underwater terrain, modelling ocean currents, tides, and even assessing climate change impacts such as beach erosion and sea level rise [1]. Scientists rely on bathymetric data to study climate change impacts, monitor beach erosion, track sea level rise, and observe subsidence or land sinking. This information is typically represented in bathymetric maps, which resemble topographic maps by using lines to depict the shape and elevation of underwater surfaces. However, the complexity and sheer volume of bathymetric

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data pose significant challenges in terms of processing, visualization, and accessibility. Traditional desktop-based solutions, while powerful, can be cumbersome and require specialized knowledge to operate. Moreover, the increasing demand for collaborative and remote access to data necessitates a more flexible and user-friendly approach. This paper details the design principles, technological framework, and key functionalities of a web-based platform developed to streamline the workflow of bathymetric data handling, from acquisition to visualization. The development of an easy-to-use application combines and automates most of the tasks that were previously carries out manually and the whole process have been simplified into a very reliable quick and efficient application. The application is developed as browser-based web application using latest frontend and backend technologies and thus can be run platform independently. The platform enhances the usability and accessibility of bathymetric data for a diverse range of users.

The objective of the work is to develop an online web-based application that facilitates the users to upload the survey data and migrate them directly into common GIS formats. Further, the bathymetric data of the entire kerala coast surveyed by the Hydrographic Survey Wing, Government of Kerala, have been uploaded and processed in the web-based application. The system is designed to transform raw XYZ data, generated by HYPACK software, into standard GIS formats and interactive 3D models, thereby lowering the barrier for non-specialists and enhancing decision-making in coastal zone management and marine research [2], [3].

2. STUDY AREA

The coastal regions of Kerala have been selected for this study. Kerala is located in the southwestern part of India, covering an area of 38,863 square kilometers with a population of 34.6 million according to the 2018 census. This narrow strip along the west coast, bordering the Arabian Sea, is flanked by Tamil Nadu and Karnataka to the east. Kerala boasts the longest coastline on the west coast of India, stretching 590 kilometers. The coastal zone of Kerala features beautiful beaches, estuaries, and lagoons, forming a unique ecological mosaic. The coastal plain, extending over 560 kilometers and rising less than 8 meters above mean sea level, comprises about 15% of the state's total area. A distinctive feature of the Kerala coast is the chain of water bodies known as "kayals," which run parallel or oblique to the coastline and are interconnected by natural or man-made canals, enabling internal navigation along much of the coast. Many perennial rivers flow into these kayals. The southern part of the Kerala coast is characterized by larger backwaters. These kayals, often separated from the sea by elongated sandbars, function as coastal lagoons. Kerala's coast is renowned for its historical sites, heritage areas, and stunning natural scenery. The dynamic processes within these coastal zones create diverse and productive ecosystems. Although coastal margins make up only 8% of the world's surface area, they contribute 25% of global productivity.

3. METHODOLOGY

The core components of the platform include a data ingestion module, a processing engine and visualization interface. The data ingestion module supports various bathymetric data formats and integrates with existing GIS databases. The processing engine, built on robust algorithms enables data cleaning, interpolation and terrain modelling. The visualization interface leverages different web technologies to render interactive 3D models of underwater topographies.

3.1 Data Preprocessing

The raw data received from Hydrographic Survey Wing (HSW) is in XYZ format generated through the HYPACK software solutions after conducting multiple hydrographic surveys. The XYZ format is a simple format for recording points in 3D space where the X values represent longitude, Y values represent latitude and the Z values represent elevation from the sea level. The next step is the data cleaning. The Z values obtained from the XYZ file generated from the HYPACK software are represented in positive values. Since these are bathymetric data, i.e., underwater topographic data, the elevation details are to be considered from the sea level. Thus, the Z values obtained from the XYZ file has to be negated in order to represent that the data refers to underwater topographic data. The X and Y values in the XYZ file are recorded as Geographic Coordinate System (EPSG:4326) which needs to be converted to Projected Coordinate System (EPSG:32643) for further processing. The cleaned XYZ data is loaded into spatial data frame and is exported to vector format (SHP). A concave hull derived from this SHP is generated to clip the extrapolated surface, ensuring that further processing is confined to the survey area [4].

3.2 Spatial Interpolation

Interpolation is the process of using points with known values to estimate values at other unknown points. Inverse Distance Weighted (IDW) technique is used to generate the depth surface from the point observations.

$$Z_j = \frac{\sum_i \frac{Z_i}{d^n ij}}{\sum_i \frac{1}{d^n ij}} \tag{1}$$

Here Z_i is value of known point

$d_{ij}$is the distance to the known point

Z_j is the unknown point

N is the specified power (mostly 1, 2 0r 3) [3]

A contour with 1(one) meter interval is generated from the clipped raster data and saved for future use. Considering the maximum and minimum values obtained earlier, the elevation data is categorised into several groups with a scale of 2 meters. Each group is assigned a colour as per the standards, where in the low depth regions are represented in red colour and blue colour for regions with higher depth. The resultant grayscale raster data (TIFF format) obtained is converted to a coloured raster data in TIFF and PNG format based on the elevation

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values and the colour coding as per the standards. The raster data (TIFF format) is used to generate binary files, that are used to build the 3D model of the survey area based on the elevation data. The binary files generated are stored for future use. The coloured raster in PNG format generated earlier is used to texture the 3D models generated and saved for future use. Additional layers which are in the form of DXF format that are generated through HYPACK software are converted to vector layer format with geographic coordinate system.

3.3 WebGIS Interface

The home page of the Web GIS application includes an interactive web map designed and developed using latest front-end technologies, such as HTML, CSS and Javascript, PHP as the backend and PostgreSQL as the spatial database. The access to the administration panel is restricted only to authenticated users of the application and only the officials designated to manage the data is given an access into the administration panel. The access is validated using login credentials and the same can be created by a user with administrator privileges in the system. The dashboard of the administration panel displays a table with details of all the previously added survey data. The details displayed in the table includes location of the survey, date of conducting survey, data uploaded username and the time of generating or building outputs. The interactive tabular view includes a filter through which a user can search and filter by providing any of the such as survey location, date of survey, etc.

A privileged user can upload data for building or generating outputs that are to be made available for users of the system. The data that is to be uploaded has to be in XYZ format generated form the HYPACK software where X value representing the longitude, Y values representing Latitude and the Z values representing the elevation. The additional layers that are to be included, has to be uploaded as a DXF file that consists of multiple unique layers. Along with these files details such as the location of survey and the date of survey also needs to be provided to a RESTful API, that processes the uploaded data and generates output as described earlier. The home page displays all the surveyed regions for which the 3D models and other additional layers that has already been generated. Upon selecting a survey area in the web GIS a popup with all the available survey years will be listed, form which the user can view more details about the data. On selecting the preferred year of survey, along with a map view that contains the generated raster data (coloured TIFF), 1 meter contour and other additional layers. The 3D model generated earlier, can also be visualised from the page. Users can select a survey region from an interactive map, view detailed information via pop-ups, and explore 3D visualizations built with open-source client-side libraries [4], [5]. The binary files generated earlier is fetched using REST APIs and displayed using a 3D visualizer. The 3D visualizer is built using latest open-source client-side 3D visualization libraries. The 3D visualizer, built using open-source libraries, allows users to explore underwater terrain from various perspectives, providing functionalities such as depth profiling and volumetric change analysis [4].

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4. RESULTS

The application processed around 261 number of harbours and 126 number of interior waterbodies and was uploaded into the repository. The platform also facilitates meta-data-based search for effective searching and filtering. The interactive Web GIS portal facilitate the visualization and navigation of the selected hydrographic survey data conducted by Hydrographic Survey Wing. Figure 1 depicts the interactive 3D visualization of a bathymetry data where the user can navigate to get the details of the corresponding bathymetry. Figure 2 shows the Depth Profile of the bathymetry where it shows the graphical view of the depth of the cross-section that have given. Figure 3 show the variation in the volume of the bathymetric or coastal area in the form of deposition or erosion of a survey site in two different time intervals. These results are consistent with earlier studies on spatial interpolation and bathymetric modelling [1], [3], [5]. Detailed analysis indicates that the IDW interpolation method produces smooth and continuous surfaces that effectively represent the surveyed underwater features, while the integration of color-coded maps and 3D models enhances interpretability. The observed volumetric variations align with documented coastal dynamics, thereby validating both the technical approach and the practical applicability of the platform [2], [4].

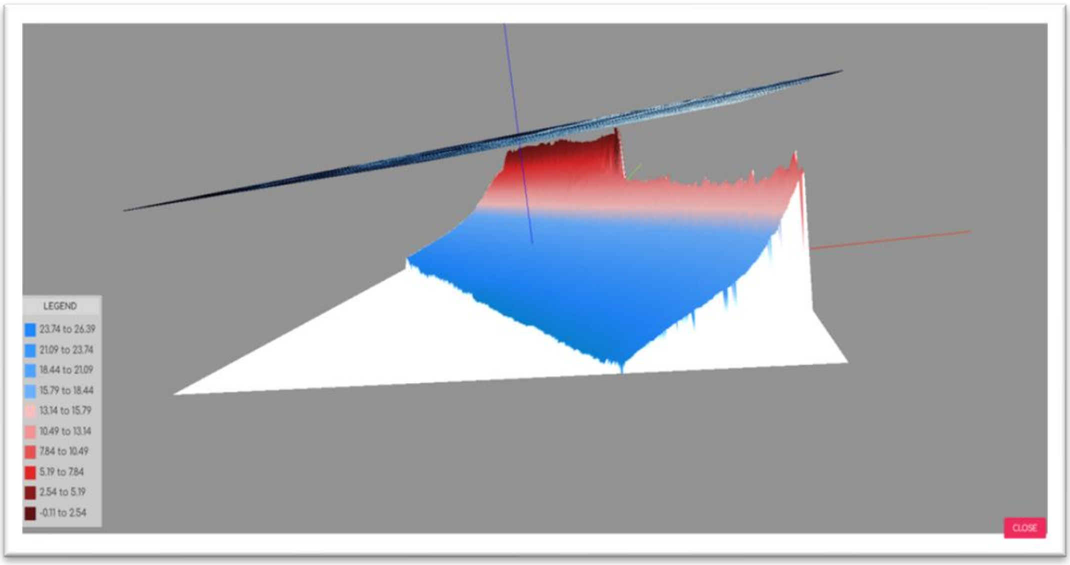

Figure 1: 3D visualization of the survey data

Figure 2: Depth Profile

Figure 3: Comparison of volume of a survey site for two different time intervals.

5.CONCLUSION

This study presents a robust web-based platform that automates the processing, modelling, and visualization of bathymetric data, thereby overcoming the limitations of traditional desktop-based solutions. By integrating data ingestion, spatial interpolation, and interactive visualization into a single, user-friendly interface, the platform not only facilitates rapid conversion of raw survey data into standard GIS formats but also enhances the accessibility and interpretability of underwater terrain information. The successful processing of extensive datasets from Kerala's coast and the detailed analysis of depth profiles and volumetric changes underscores the platform's potential to support coastal engineering, environmental monitoring, and marine research. Future research will focus on incorporating advanced predictive algorithms and expanding the range of integrated environmental parameters.

Conflict-of-Interest

The authors declare that this research was funded by the Hydrographic Survey Wing. Gerosh Kumar V is affiliated with the Hydrographic Survey Wing. However, the funding agency had no influence on the study design, data analysis, or interpretation of the results and manuscript preparation. The authors have no other conflicts of interest to disclose.

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