Real-Time Visualizations of Ocean Data Collected By The NORUS Glider

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ABSTRACT

NORUS, the North America-Norway educational program, has a scientific focus on how climate-induced changes impact the living resources and ecosystems in the Arctic. In order to obtain the necessary science data, the NORUS program utilizes the Slocum Glider, a form of Autonomous Underwater Vehicle (AUV). This project aims to create a compelling, efficient, and easy to use interactive system for visualizing large sets of science data collected by the glider. This goal is obtained through the implementation of various methods taken from scientific visualization, real time rendering, and scattered data interpolation. Methods include visualizations of the surrounding terrain, the ability to map various science data to glyphs, control over color mapping, scattered data interpolation and interactive camera control.

1 INTRODUCTION

The oceans are an important focus of scientific study and exploration. NORUS, the North America-Norway educational program, has a scientific focus on how climate-induced changes impact the living resources and ecosystems in the Arctic. In order to obtain the necessary science data, the NORUS program utilizes the Slocum Glider, a form of Autonomous Underwater Vehicle (AUV). This project aims to create a compelling, efficient, and easy to use interactive system for visualizing large sets of science data collected by the Slocum Glider. This goal is obtained through the implementation of various methods taken from scientific visualization, real-time rendering, and scattered data interpolation. The system was written entirely in C++, using OpenGL and GLSL for graphics and Qt for rapid development of a platform independent graphical user interface. It allows for the real-time rendering of offline ocean data. The primary dataset used is from a glider deployment in a fjord of Svalbard, Norway. The glider's mission spanned from longitude 13.3042° East to 16.6875° East and latitude 78.1042° North and 78.7042° North. The 17 day mission began on June 30, 2009, during which time the glider collected 242,693 measurements for each of the 20 different on-board sensors.

The system uses a generic mesh loader to generate an accurate and compelling environment. The look of the environment is obtained through the use of multitexturing to produce detailed terrain, a quasi-realistic ocean surface with reflection, refaction, and specular highlighting, and simple animated clouds generated by 3-D perlin noise. Also, various user configured scientific visualizations allow the user to analyze the measurements taken by the glider. They include glyphs that display the discrete data measurements and interpolated visualizations such as isosurfaces, gradient planes, and volume slices that provide interpolated values across continous surfaces. An interactive camera control allows the user to freely move through the environment and a virtual glider retraces the physical glider's mission path. Finally, an intutive graphical user interface provides the user with the highest possible level of customizability across the entire system. Initial feedback from NORUS biologists working on the project conveyed enthusiasm for a tool that allowed them to visualize their data in a virtual environment. Many of the tools included in the system were defined and refined through feedback from biologists about what they would like to be able to see and what parameters they needed to be able to control.

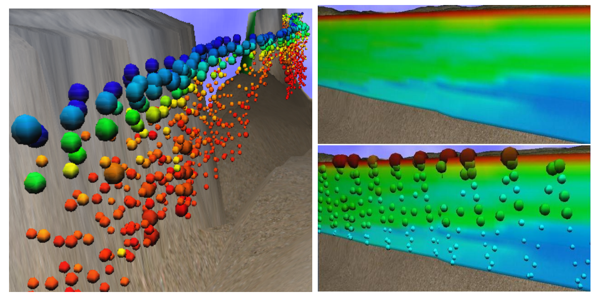

Figure 1: On the left: Glyphs with size mapped to chlorophyll and color mapped to salinity. On the right: A temperature mapped mission defined gradient planes, the glyphs in the lower image show how the interpolated values coorelate to discrete measurements.

2 RELATED WORK

Several visualization systems have been developed for specific underwater visualizations. Some related systems include the underwater virtual world developed at the Naval Post Graduate School [4], Collaborative Ocean Visualization Environment (COVE) [8], which is a set of collaborative tools used to support deep-water ocean observatories. Other related work designed by the Monterey Bay Aquarium Research Institute (MBARI) in 1999 [10] was aimed at creating 3-D oceanographic data visualizations for the web. Chapman, Wills, Stevens, and Brookes [5] present a system that generates post-survey visualizations of underwater pipelines and a system that genereates real-time visualizations of the clear-up operation of a former U.S. Nuclear Submarine Base [6].

Another important field of related work is scattered data interpolation[1, 7]. For this project, we found that scattered data interpolation was best achieved using radial basis functions[2]. Radial basis functions (RBFs) are a simple and useful tool for interpolating data in almost any number of dimensions. Given a set of data points with associated values, RBFs construct a smooth and continous function which interpolates the values at each data point.

3 RESULTS

The system presented in this poster addresses the problem of creating an interactive underwater visualization system capable of handling very large and diverse sets of science data collected by AUVs such as the Slocum Glider. Beyond that, the system also provides a high level of configurability for each individual visualization.

Figure 1 provides a view of glyphs with size mapped to chlorophyll and color mapped to salinity, with dark blue corresponding to the lowest values. Simple analysis shows that the salt content is lowest at the surface of the water and increases steadily until approximately one third of the glider's maximum depth, where it stays fairly consistent. For the most part, there appears to be an inverse correlation between chlorophyll levels and salt content, with regions of variability.

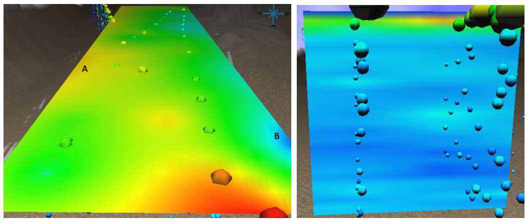

Figure 2: On the left, an image of chlorophyll mapped volume slice along the ocean surface, while on the right is an image of chlorophyll mapped volume slice in the YZ plane.

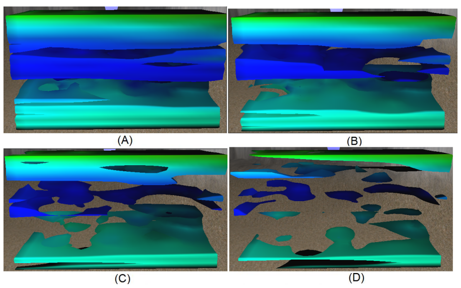

Figure 3: A sequence of views for a chlorophyll mapped isosurface with temperature mapped to color.

3.1 Scattered data interpolation visualizations

The system generates interpolated data using a radial basis function interpolation from the scattered data gathered by the glider. This interpolated data can be visualized as gradient planes, volume slices or isosurfaces. Each gradient plane is constructed so that it spans vertically from the sea level to the deepest depth reached by the glider. Figure 1 shows gradient planes following the gliders path. Volume slices are shown in Figure 2, where a chlorophyll mapped volume slice is shown along the ocean surface. The slice is being rendered at a resolution of 50x50 with a value range of 0.8712 to 3.4606. The glyphs represent discrete data samples used to generate the interpolation function for the region. The important thing to note is the coorelation between color of the glyphs and the color of the volume slice. Figure 2 also provides a view of a chlorophyll mapped volume slice along the YZ plane. The slice generates interpolated values for the area inbetween the two distinct glider passes that are defined by the position of the glyphs.

Figure 3 provides a sequence of views for a chlorophyll mapped isosurface with temperature mapped to color. Figure 3A is defined with an isovalue of 0.9, and in each successive image the isosvalue is increased by 0.05, resulting in figure 3D being mapped to an isovalue of 1.05. The color of each isosurface is mapped to the temperature within the region. Figure 4 provides two views for a chlorophyll mapped isosurface with salinity mapped to color. Figure 4A is mapped to an isovalue of 0.9 and figure 4B is mapped to 0.95. The color of both isosurfaces are mapped to the salinity levels within the region.

4 Conclusion

This project has presented a compelling, efficient, and easy to use interactive system for visualizing large sets of science data collected by the Slocum Glider. An interactive camera allows the user to navigate through accurate terrain generated from bathymetry data. The visualization system constructs glyphs, mission defined gradient planes, user defined gradient planes, volume slices, and isosurfaces. Although the glyphs are generated from discrete data measurements taken by glider, all other visualizations, known as interpolated visualizations, use scattered data interpolation to allow continous sampling over regions containing a discrete number of data measurements. The system was developed iteratively to ensure that it would be a useful tool for the biologists involved in analyzing and interpreting the glider data. At the completion of each iteration, the system was presented to NORUS biologists to obtain user feedback and gather additional requirements for the next iteration. Overall, user feedback was extremely positive, and the biologists were excited to have an additional tool for visualizing the glider data.

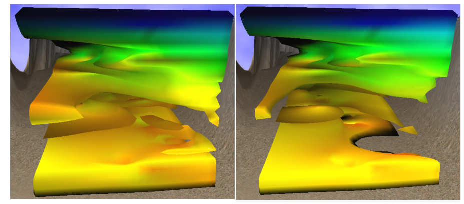

Figure 4: Two views for a chlorophyll mapped isosurface with salinity mapped to color.

Acknowledgements

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